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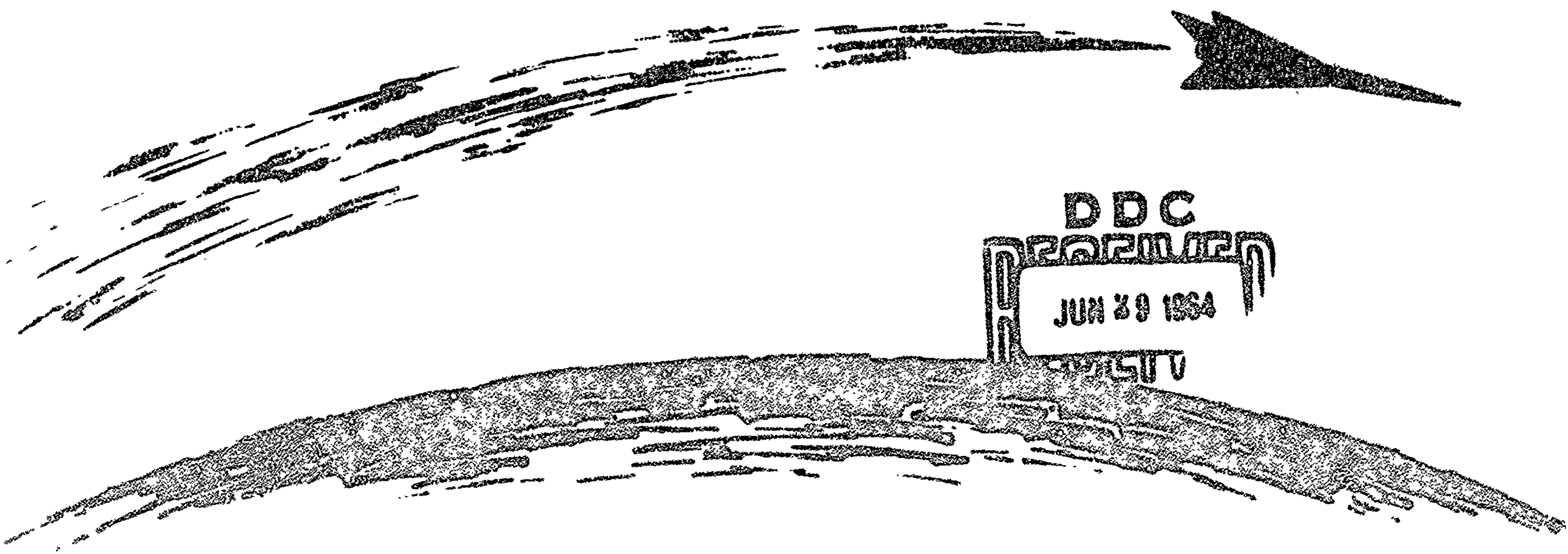
SUPERSONIC TRANSPORT

FEDERAL AVIATION AGENCY



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SUPERSONIC TRANSPORT DEVELOPMENT PROGRAM

This report describes the program for the development of a commercial supersonic transport aircraft as approved by the President.

June 19, 1963

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SUMMARY

The supersonic transport represents the next inevitable advance in commercial aviation.

The rate of growth of aviation in the United States has been closely related to the growth in safety and speed of transport aircraft.

The United States manufacturing and air carrier interests are important to the welfare of the United States.

A supersonic transport in commercial service is assured by the British/French program to develop the Concorde.

The British/French Concorde will be introduced into commercial passenger service in 1970 carrying 96-104 passengers with a range of 3750 statute miles and a design speed of Mach 2.2.

There is a potential initial market for United States supersonic transport for 200-250 aircraft.

There will be a foreign market for a United States supersonic transport ranging from $2 to $3 billion over a 10-year period.

There are three basic risks involved in any development program for a supersonic transport:

1. that technological problems cannot be satisfactorily overcome.

2. that a supersonic transport will not have satisfactory economics.

3. that sonic boom overpressures will result in undue public disturbance.

The design characteristics of the commercial supersonic transport should optimize safety and economical performance. Design objectives should be: Range - 4,000 statute miles; Payload - 35,000 pounds based on 163 passengers (tourist) plus 2,000 pounds cargo; Service life - 36,000 hours; Airports - operable within present intercontinental airports; Operating costs - comparable to subsonic jet transports; Cruise sonic boom - 1.5 pounds per square foot or less.

The precise design speed objective should be determined after the initial design competition and should be optimized at a speed which will yield greatest safety and economic characteristics.

A United States supersonic transport has the potential of achieving a degree of profitability equal to today's subsonic jets operated in the international service.

The development program will consist of three phases:

Phase I: initial design competition beginning in August 1963 and extending over a period of 5 months at no cost to the Government.

Phase II: the detailed design phase lasting approximately one year requiring Government funding in the order of $60 million.

Phase III: development of the transport through FAA certification by one airframe and one engine manufacturer at cost ranging from $700 to $900 million, depending upon the design characteristics determined by the Government.

Under the development plan the United States can place a supersonic transport in commercial service in or before June 1970.

All of the factors and the related weights to be used in determining the winners of the design competition will be made public prior to initiation of the competition.

The supersonic transport development program is essentially a commercial venture with government participation because of the substantial cost of the program.

Every effort will be made to preserve the normal relationship between manufacturers and air carriers.

The total cost of the development program should not exceed $1 billion. The selected manufacturers will be required to participate in the financing of the development program for an amount not less than 25 percent of the total contract cost of the program.

The airlines will be required to repay the remaining Government development costs through a royalty arrangement.

There are five major decision points, which are critical in the development program, at which the program can be terminated if it seems unlikely that stated objectives can be attained.

It is estimated that the production cost of the Mach 2.2 aluminum supersonic transport will range from $13 to $15 million each; the estimated cost of a steel/titanium Mach 3 transport will be approximately $22.6 million each.

The Government will not share production costs although there may be a requirement for the Government to sponsor guaranteed loans to assist the manufacturers in meeting "work in process" financial requirements.

The Government does not plan to pay operating subsidies to airlines for operation of the supersonic transport.

The President of the United States has designated the Federal Aviation Agency to supervise the supersonic transport development program.

Although exact staffing requirements are not finally determined, it is expected that a staff of no more than 100 administrative and technical personnel will be required to supervise this program.

THE SUPERSONIC TRANSPORT AND THE NATIONAL INTEREST

CONSIDERATIONS FAVORING DEVELOPMENT

The supersonic transport represents the next inevitable advance in commercial aviation.

The development of a supersonic transport is a logical step in pursuing the national objectives of an aviation system that contributes to the economic growth, national security, culture, and international commerce. These are the objectives laid down by the Congress in the Federal Aviation Act of 1958.

Product superiority and improvement is essential to the continued growth and prosperity of any industry. The air carrier industry is no exception.

The rate of growth of aviation in the United States has been closely related to the increased safety and speed of our transport aircraft. The supersonic transport will continue this natural evolution as a normal step forward in creating more desirable commercial air transportation systems. The history of aviation has been a constant effort to shorten travel time between major areas of the world. From 1944 to the present, for example, the schedule time between Los Angeles and New York has decreased from approximately 12 hours to about 5 hours. The supersonic transport will reduce this travel time to approximately 2 hours and 30 minutes.

The United States air carrier industry employed over 171,000 people, expended $4.2 billion in 1962, and produced nearly 44 billion revenue passenger miles. The growth in this industry in the last 10 years has been dramatic -- traffic has increased almost three-fold since 1952. Air transportation has made, and will continue to make, substantial contributions to the economic welfare of the country as well as provide a vital link between the U.S. and the free countries of the world.

The British and French Governments have recognized the importance of the supersonic transport in approving action in the development of the Concorde. They have marshalled their technological resources and have earmarked $450 million for the development program.

A United States transport with the required safety and economic characteristics would strengthen U.S. industry and maintain U.S. leadership. In the recommended program, the Government is providing the funds to initiate development with the clear understanding that the aircraft should be economically self-sufficient and repay the government outlays over a period of time.

The airframe and engine industries of the United States represent technological resources which should not be allowed to deteriorate. Failure to progress in technology will deprive the United States of the basic technological capabilities required to produce the next family of transport aircraft. The development and production programs will ensure the maintenance of necessary technological skills in the aeronautical and supporting industries. It is estimated that an average of 30,000 to 45,000 engineers, technicians, and skilled workers in aeronautical and supporting industries would be employed over a 15-year period.

There is a potential initial market for a United States supersonic transport of 200 to 250 aircraft.

There will be a potential foreign market for a successful U.S. transport of approximately 115 aircraft having a sales value of $2 to $3 billion, depending on the unit price.

RISKS

Despite the compelling reasons for the United States to initiate a development program, it must be recognized that significant risks will be incurred. These are:

The risk that the industry cannot surmount the technical problems involved in producing a transport which can operate continuously at supersonic speeds. The technical problems are substantial, but the expenditures of hundreds of millions of dollars in

the development of supersonic military aircraft, such as the B-58 and the B-70, and the $31 million FAA/NASA/DOD supersonic transport research program, beginning in 1961, provide a sound technological background.

The risk that the developed supersonic transport may not have the requisite economic characteristics to permit it to operate profitably in commercial service. It is reasonable, however to assume that United States industry and government technological resources can meet this challenge.

The risk that the supersonic transport will produce sonic boom ground overpressures which will result in adverse public reaction. This is a problem of major magnitude which might restrict domestic operations. However, it can be alleviated, at least to some extent, through aircraft design characteristics and less desirable routings.

FOREIGN COMPETITION

BRITISH/FRENCH PROGRAM

The information available indicates that the British/French program is focused on development of a transport with the following design objectives:

1. Payload of 96 - 104 passengers with limited allocation of capacity for cargo or mail. The gross weight of the aircraft will probably range from 264,000 pounds to 290,000 pounds.

2. Initially may provide first-class accommodations only. However, the small size of the cabin will require a much tighter seating arrangement than in present subsonic jets. The size also tends to preclude effective arrangements for two-class service.

3. Range planned for approximately 3750 statute miles, or New York-Paris nonstop.

4. Design speed of Mach 2.2. Transonic acceleration altitude of about 40,000 feet based on an improved Olympus engine.

5. Aluminum construction with titanium or steel probably used in certain temperature-critical areas.

6. Sonic boom intensities at transition altitudes in the range of 1.75 to 2.2 pounds per square foot. Cruising overpressures generated are estimated to be about 1.5 pounds per square foot.

7. Aircraft systems, instrumentation, structure, and maintainability techniques based on existing practices.

8. First commercial flight of the Concorde is planned for January 1970.

9. Estimated delivered price of from $7 million to $10 million. These price estimates apparently exclude amortization of development costs, which would be absorbed by the two Governments to keep the price within this range.

There may be some doubt that the British/French development program will attain these design objectives. As the program proceeds, there will undoubtedly be some changes in these design characteristics. It cannot be assumed, however, that the net result will be to lessen the competitive impact of the aircraft. It would be unwise for the United States to assume that these objectives will not be substantially attained since both the British and French Governments have fully mobilized their aeronautical resources and have earmarked approximately $450 million for the development program.

MARKET POTENTIAL FOR THE SUPERSONIC TRANSPORT

The estimates of market potential are based in large part upon a comprehensive study made by the Stanford Research Institute. Their conclusions are in general agreement with the findings of the Supersonic Transport Advisory Group and estimates of United States manufacturers and the International Civil Aviation Organization.

BASIS FOR MARKET ESTIMATES BY STANFORD RESEARCH INSTITUTE

1. Scheduled commercial air passenger traffic in the Free World is expected to grow from over 81 billion revenue passenger-miles in 1962 to almost 229 billion passenger-miles in 1975.

2. In 1973, the earliest probable year for supersonic transport fleet operations, Free World passenger traffic is expected to total almost 200 billion passenger-miles.

3. Of the total 200 billion passenger-miles anticipated in 1973, approximately 87 billion passenger-miles, or 43% of the total world market, are expected to be potentially available to the supersonic transport. This assumption is based on trans-Atlantic range capability.

4. Potential traffic for the same period was analyzed for the 60 major airlines who carry more than 90% of all Free World traffic. The historical growth pattern, route structure, operating policies and future potential of each carrier were examined to determine that part of each carrier's traffic potentially suitable for supersonic transport operations.

MARKET ESTIMATES BY STANFORD RESEARCH INSTITUTE

The Stanford Research Institute estimated the total world market potential for a Mach 2 and a Mach 3 transport.

TOTAL SST WORLD MARKET POTENTIAL
First-Round Orders
(Numbers of 140-Seat Aircraft)

Conditions Assumed	Mach 2 Only[a]	Mach 3 Only[a]
No fare increases and no operating restrictions	378	325
Fares 10-15% above present level	364	312
All first-class fares	123	99
Restrictions on overland flights because of sonic boom (no fare increases)	220	185

a. Numbers are not additive.

The comparative market potential for a United States Mach 2 transport and the Concorde (based on the assumption that the United States aircraft will be available within two years of the Concorde and has trans-Atlantic capability):

U. S. Mach 2 market potential	250
Concorde market potential	128
Total	378

The market potential for a Mach 3 transport having trans-Atlantic capability is:

U. S. Mach 3 market potential	216
Concorde market potential	125
Total	341

OTHER FACTORS TO BE CONSIDERED

The market potentials for the supersonic transport as estimated by the Stanford Research Institute are considered to be reasonable.

It should be noted, however, that the Institute in making this market study, based its estimates on a hypothetical aircraft which is believed to be less commercially attractive than is possible to attain through a United States development program.

A supersonic transport having sound economic characteristics may, therefore, create a potential market substantially in excess of the estimates by the Institute.

DESIGN CONSIDERATIONS FOR A UNITED STATES SUPERSONIC TRANSPORT

OBJECTIVES

The United States supersonic transport should have the following design objectives:

1. A range which will permit it to serve most of the major markets of the world on a non-stop basis. The most desirable range appears to be approximately 4,000 statute miles (Los Angeles-New York is 2500; New York-Paris is 3700). Less than 15 percent of the potential traffic available to the supersonic transport is beyond a nonstop range of 4000 miles. (See Chart No. 1)

2. A maximum gross weight of 350,000 pounds.

3. A payload of 35,000 pounds or more, based upon 163 passengers (all-tourist configuration) and 2000 pounds for cargo and mail. It will be desirable, but may not be possible, to achieve a payload as high as 40,000 pounds.

4. Ability to accelerate through the transonic speed regime at altitudes above 42,000 feet to ensure that sonic boom overpressures during acceleration will not exceed 2 pounds per square foot.

5. Ability to cruise without creating sonic boom overpressures of greater than 1.5 pounds per square foot.

6. Capability of safely operating at airports which accommodate the current international subsonic jets.

7. Noise resulting from landing and take-off operations not greater than that presently created by the current international subsonic jet transports.

8. Handling characteristics equal to those of the current international subsonic jet transports.

9. Design speed better than Mach 2.2

10. Service life of at least 36,000 hours.

The primary objective of the United States development program should be to produce a commercial transport with satisfactory safety and economic characteristics.

FACTORS INFLUENCING DESIGN SPEED

It will be necessary to optimise basic design parameters in order to ensure an effective transport. The configuration of the aircraft in terms of lift-drag ratio, propulsive efficiency, design weight requirements, and speed must be optimised. These parameters will establish, to a large degree, the fundamental economics of the aircraft. The various operational requirements must be achieved without serious degradation of the economic characteristics. This inherent conflict will require a high degree of design ingenuity.

The British/French development of the Concorde with an ultimate design speed of Mach 2.2 establishes the lowest speed capability which the United States should consider.

Within the speed regimes between Mach 2.2 and 3, the higher speeds permit the aircraft to attain better cruise efficiency. This factor, however, is only one consideration in optimizing design speed.

It has been generally assumed that a United States supersonic transport should have a speed capability of Mach 3. The view that Mach 3 cruise speed is required "to advance the state of the art," however, must be considered subordinate to the objective of developing a transport with sound economic characteristics.

PRODUCTIVITY VS. PROFITABILITY

The true value of speed must be reflected in aircraft productivity versus operating costs.

Productivity is the number of seat or revenue-ton miles a commercial aircraft can generate in a given period. This total multiplied by the unit price charged for passengers and/or cargo will be the earning capacity of the transport. It is influenced by factors such as speed, utilization, and capacity.

Speed alone, however, is not the single determinant of productivity. If an increase in speed results in a proportionate increase in productivity at no more than a proportionate increase in operating cost, it becomes economically justifiable. If productivity increases at a greater rate than operating cost, an aircraft will have greater profitability.

Chart No. 2 indicates that the difference between productivity at Mach 2.2 and productivity at Mach 3 is not in proportion to the difference in speed. Over the New York-Paris range, productivity of the Mach 3 is 15% greater than the Mach 2.2. For shorter ranges, the productivity advantage of the Mach 3 is even less favorable. Under these conditions, a Mach 3 transport would normally possess inferior economic characteristics.

As design studies continue, it may be demonstrated that a transport having speeds greater than Mach 2.2 will have equivalent, or better, economic characteristics.

Chart Nos. 3 and 4 indicate the flight times over representative stage lengths for subsonic, Mach 2.2, and Mach 3 transports. In airline service, there is a relatively small difference in flight time between Mach 2.2 and Mach 3. As the range decreases, these differences become minimal.

TEMPERATURE CONSIDERATIONS

The principal problem associated with speed is temperature, which increases as the square of the speed. Maximum temperatures which will be encountered at a cruising speed of Mach 2.2, on the hottest surfaces of the airframe, will be in the order of 306°F. The maximum temperatures encountered at Mach 3 will be in the order of 600°F; at Mach 3.5, 882°F. (See Chart Nos. 5 and 6).

The substantially higher temperatures resulting from higher cruise speeds not only dictate the type of materials used in aircraft structures, but also have a substantial effect on the design requirements for subsystems and other components. For example, seals, lubricants, fuel, rubber and plastics and other nonmetallics present problems at the higher temperatures.

There is general agreement that the technological risk is greater in the higher temperature regimes.

A design objective of Mach 2.2 will permit the use of aluminum in airframe construction, supplemented with steel or titanium for areas subject to the highest temperatures. There is some disagreement as to the likelihood of attaining a satisfactory service life for an aircraft constructed primarily of aluminum. The additional structural weight required for satisfactory life at cruise speeds of Mach 2.2 may impose an economic penalty on an aluminum aircraft. The possibility, however, of using an aluminum structure which can be internally cooled should not be overlooked.

At cruising speeds above Mach 2.2, there is consensus that steel and/or titanium should be used as primary materials. The technique of aircraft construction using steel is relatively new. The only large supersonic aircraft using this metal is the B-70, which is still in the development stages. Steel is more costly than aluminum as a material and also requires a greater number of production manhours.

Titanium is substantially higher in cost, at the present time, than steel or aluminum. Titanium, however, offers a number of advantages, principally in the areas of lower structural weight requirements and increased service life of the aircraft. While titanium has been used to some degree in the fabrication of the B-70, and other aircraft, it is a relatively new material to the airframe industry, particularly with reference to major structural application.

There is consensus in the airframe industry that titanium should receive serious consideration for use as the structural material for the supersonic transport; much work is being done in the development and fabrication of titanium at this time. It offers possibly the best opportunity to achieve satisfactory payload capability.

In view of these considerations, the decision on speed will be made after completion of the initial design competition to permit the manufacturers to determine the optimum speed after careful consideration of all factors affecting safety and economies. Another factor which indicates that this may be appropriate is that NASA's configuration studies for both Mach 2.2 and Mach 3 will not be completed before October 1963, although substantial results should be available by late summer, 1963.

SUPERSONIC TRANSPORT GROWTH POTENTIAL

In the initial design of the supersonic transport, the possibilities of growth in terms of speed, range, and payload must be given consideration.

The subsonic jets have had relatively little growth in speed. There have been significant increases, however, in payload and range as well as improvements in operating economy. The initial subsonic transports utilized the J-57, J-75, and J-79 engines which were developed by the Department of Defense for military applications. The requirement to improve economic characteristics resulted in the development of the turbofan versions of the J-57 and J-79. These engines provide increased thrust and more favorable economic characteristics because of lower fuel consumption. The civil development of the fan engine has been the key to the improved economic characteristics of the subsonic commercial jets.

In considering the proposed supersonic transport, however, and its ultimate growth potential, the situation is somewhat different. In the design of the supersonic transport and its associated power plants, it will be necessary to achieve the highest degree of flight efficiency through the optimum mating of airframe and engine. If the power plant is not designed precisely to take advantage of the aerodynamic configuration of the aircraft, an operating penalty will result. Therefore, any attempt to change the speed characteristics of the transport, either through aerodynamic modification or power plant changes, may result in a payload or range penalty.

It does not appear to be realistic to assume a growth in speed without substantial redesign of either the airframe or engine. The most reasonable approach to growth of the supersonic transport is that, as the state-of-the-art advances, modification of the airframe and/or engines may permit improvement in range and/or payload characteristics. It should be emphasized, however, that if the initial design point results in optimum characteristics, there may be relatively little opportunity for the supersonic transport to grow in speed without substantial additional investment in redesign.

THREAT OF OBSOLESCENCE

There may be apprehension that, if the United States develops and produces a supersonic transport with cruising speed lower than Mach 3, foreign competition may develop a Mach 3 transport which could have serious impact on the United States aircraft.

The design objective in the development of the United States supersonic transport will be to produce an aircraft with the maximum operating economies, regardless of the specific speed capability. If this objective can be attained, there is little or no possibility that, in the same time period, an aircraft having a greater speed would possess equal economic characteristics.

In addition, such a development would require substantial expenditures by any Government, since there would be a mandatory requirement for a new airframe and engines. The risks which would face any foreign Government in a project of this nature would seem to indicate that the fear of foreign competition is not justified.

It is entirely possible, however, that the next generation of commercial transports will obsolete any supersonic transport. For example, there are indications that a hypersonic transport employing cryogenic fuels (such as liquid hydrogen) and operating at speeds of Mach 6 and above may prove to be substantially better than a supersonic jet.

The hypersonic transport would have to be designed to operate in temperatures in excess of $1800^{o}F$ and to employ new propulsion systems as well as structural materials. It is believed that such a development is still some distance in the future.

SONIC BOOM

Sonic boom, which results from shock waves produced by an aircraft in supersonic flight, will present a major problem. These ground overpressures, like the sound of thunder, may be of sufficient intensity to disturb the public along the flight path. It is necessary, therefore, that approval of the supersonic transport program carry with it recognition that supersonic flight will cause some disturbance to people on the ground, barring an unforeseen breakthrough in technology.

There is little doubt that transonic acceleration at altitudes of 40,000 feet or above will produce sonic boom overpressures in the order of 2 pounds per square foot. These momentary acceleration effects, such as the rattling of windows, will occur after the aircraft has traveled approximately 150 miles from the take-off airport.

During cruise, the supersonic transport may create a constant overpressure effect in the order of 1.5 pounds per square foot or less. Chart No. 7 shows the estimated overpressures for a Mach 2.5 supersonic transport with an intercontinental take-off gross weight of 350,000 pounds. The chart also shows the reductions in sonic boom overpressures when the aircraft is operated at shorter stage lengths in domestic service. The reductions result from the lower gross weight of the aircraft due to reduced fuel requirements.

The sonic boom overpressures will be projected along the line of the flight path. Booms will be noticeable at distances of approximately 25-30 miles to either side of the flight track. The boom will deteriorate to less than 1 pound per square foot at approximately 12 miles either side of the flight path.

It is believed that there will not be damage to ground structures at the overpressures predicted for the supersonic transport.

The achievement of the normal levels of sonic boom overpressures will require precise planning of supersonic flights. Any significant change in the flight path during acceleration or cruise could result in a substantial increase in ground pressure effects. These effects may also momentarily increase, substantially, as a result of meteorological and atmospheric conditions. Conversely, certain meteorological and atmospheric conditions may result in the momentary elimination of sonic boom overpressures during flight.

There can be little question that communities under the supersonic transport flight path will be disturbed, probably to a greater extent at night than during the day. There is no certainty, at this time, that substantially lower levels of sonic boom created by supersonic flight overpressures can be attained. However, technological problems of this magnitude have been solved in the past and research to explore possible means of reducing overpressures will continue.

Studies have been conducted by the National Opinion Research Center of the University of Chicago to determine the probable public reaction to sonic boom. (Chart No. 8) Their findings to date indicate that there will be some public reaction to the overpressures of 1.5 pounds per square foot and increasing reaction at higher pressures.

It should be noted, however, that many activities today in metropolitan areas result in disturbance factors greater than those resulting from sonic boom overpressures.

SUPERSONIC TRANSPORT OPERATING ECONOMICS

The true measure of the supersonic transport development program will be determined by the aircraft's success in commercial service. The primary qualities which are required are safety in operation and ability to demonstrate profitable operation in commercial service.

One measure of a transport's economic potential is direct operating costs. It is apparent, however, that direct operating cost estimates for an aircraft which is not yet designed are subject to a degree of uncertainty.

Direct operating costs include depreciation, crew cost, insurance, fuel, oil and maintenance. It should be noted that the direct operating costs of new type aircraft tend to decrease with time as operational and maintenance procedures are improved. The following table indicates that experience of three airlines using the 707 or DC-8 in U. S. domestic service at an average stage length of approximately 900 miles.

DIRECT OPERATING COST (CENTS PER SEAT MILE)

Year	Airline "A" DC-8	Airline "B" 707	Airline "C" 707
1959 (1st full jet year)	2.84	1.95	1.73
1960	1.84	1.93	1.45
1961	1.59	1.64	1.56
1962	1.44	1.40	1.58

It is reasonable to expect direct operating cost improvement, in a similar fashion, when the supersonic transport is introduced into commercial service.

COMPARATIVE PROFITABILITY

The cost of operating a supersonic transport has been compared with current and future subsonic jet transports.

For this purpose each aircraft configuration has been based on the maximum number of seats using normal tourist configuration.

Chart Nos. 9 and 10 illustrate the comparative profitability of five different aircraft. It should be noted that the aircraft designated as "present subsonic jet" with 179 seats is based upon the composite characteristics of the intercontinental versions of the DC-8 and 707 in all-tourist configurations. This is not representative of the manner in which these aircraft are currently operated since there is normally an intermixture of tourist and first-class services.

It should be further noted that the comparison is based upon the maximum stage length for the supersonic transport (New York-Paris) and the indicated annual earnings are not representative of true airline operations, where a single aircraft will normally operate over varying stage lengths.

The charts present one comparison of profitability of a proposed supersonic transport and subsonic jets of various sizes under the assumptions which are indicated in chart Nos. 11 and 12.

It has been generally assumed that the supersonic transport would require higher fares than current subsonic jets in order to operate profitably in commercial service.

On the basis of this study, it seems reasonable to forecast that a supersonic transport which substantially meets the design objectives would compare favorably with current subsonic jets, even at fares 20% lower than the current New York-Paris economy fare.

Relatively small changes in design parameters of the supersonic transport will dictate its commercial profitability, and unless the objectives specified in Chart No. 12 can be substantially attained, the aircraft will probably not be satisfactory in commercial service.

If at the end of Phase II it is clear that the required economics cannot be attained, the development program should be re-evaluated and probably terminated.

On the basis of studies conducted to date, however, it is evident that the transport does have the potential for satisfactory commercial characteristics and that there is a reasonable chance that this aircraft will prove to be as good or perhaps better than any transport operating today.

RETURN ON INVESTMENT

The supersonic transport may not be able to demonstrate a return on investment in airline service comparable to that of existing subsonic transports, if it is assumed that the supersonic transport in competition with subsonic transports would have the same load factor. Traditionally, however, the faster aircraft has carried the majority of traffic. Therefore, in competition with the subsonic jets, the supersonic transport may in practice have a comparable or greater return on investment.

If, however, all subsoni transports in medium and long range service were replaced by supersonic transports, it appears doubtful that the return on investment for the supersonic transport would equal the return for a subsonic transport fleet.

This is because one supersonic transport costing approximately \$22.6 million would probably replace only two to two and one-half subsonic transports costing approximately \$6.5 million each, or a total of \$13 to \$16 million.

If, however, the supersonic transport has better economic characteristics than assumed in the examples, the return on investment might equal or exceed that for the subsonic jets.

It should be emphasized that, regardless of whether the United States develops a supersonic transport, the U. S. subsonic fleets will be placed in direct competition with the British/French Concorde with deleterious effects upon revenues of U. S. carriers.

The Concorde may not meet required economic characteristics. If a U. S. supersonic transport is not available, U. S. airlines, compelled for competitive reasons to purchase Concordes, would face the serious penalty of operating against subsidized foreign airlines.

DEVELOPMENT PROGRAM

Development includes all phases of the program from the initial design competition to Federal Aviation Agency certification for passenger and cargo service.

U.S. TECHNOLOGICAL CAPABILITY TO DEVELOP A SUPERSONIC TRANSPORT

The engine and airframe manufacturers of the United States lead the world in supersonic technology. The development of the Mach 2 B-58, the Mach 3 B-70, the hypersonic X-15, and other high performance military aircraft have required intensive research and development. The Department of Defense and NASA have, over a period of years, expended several hundred millions of dollars for these projects. The resultant advances in technology will prove of material value to the supersonic transport development program.

The Congress has appropriated $31 million to the FAA for research related specifically to the supersonic transport. These funds, augmented by industry participation and programs carried on by NASA and DOD, provide additional information of direct value to the program.

The United States also has a substantial background in supersonic flight. The operation of the B-58 bomber at supersonic speed has given the United States knowledge of the various problems of large aircraft operating in the supersonic flight regime. This information, together with data which will be gained from flights of the B-70, will prove invaluable in the development of the supersonic transport.

Supersonic development costs could be substantially reduced if a current military engine could be used. Two Mach 3 engines, the J-58 and J-93, have been developed.

These engines were designed to satisfy military requirements and do not have the rated thrust required to permit the supersonic transport to accelerate to supersonic speed at altitudes above 40,000 feet. This acceleration altitude is a firm requirement which is necessary to avoid unacceptable sonic boom overpressures. The J-58 and J-93 have thrust ratings of

approximately 30,000 pounds. It is generally agreed that the supersonic transport in a four-engine configuration will require engines with a thrust rating of approximately 40,000 pounds per engine.

It has been determined that it is not practicable to modify the military engines to meet commercial transport requirements.

DEVELOPMENT PLAN

The development plan for the supersonic transport will consist of two, or possibly three, phases.

Phase I; an initial design competition between all interested airframe and engine manufacturers to be started in August 1963 and extending over a period of five months. This competition, at no cost to the government, will permit all manufacturers to present their design concepts and program plans to meet the design characteristics specified by the Government.

Selection of the airframe and engine manufacturers for the development program will be made if a clearly superior and "winning combination" results from Phase I. If not, competition between two airframe and two engine manufacturers would be continued through Phase II.

Phase II; the detailed design phase lasting approximately one year.

This phase will include development of detailed drawings, specifications, mock-ups, cost analyses, wind tunnel and laboratory tests.

The Government will provide financial assistance of approximately $60 million for Phase II.

<u>Phase III</u>; development of the transport through FAA certification by one airframe and one engine manufacturer.

Cost estimates of Phase III range from $700 million to $900 million, depending on the specific design characteristics determined by the Government after consultation with United States airlines and as a result of the Phase II competition.

The development plan outlined above will permit the United States to place a supersonic transport in commercial service in or before June 1970. (Chart No. 13)

The timing of the development plan is based upon the requirement for a Mach 3 steel-titanium transport. It may be possible to complete the program at an earlier date depending upon the design characteristics which are finally determined for the transport. For example, a Mach 2.2 aluminum transport could be made available in 1969.

The development plan provides for 1500 hours of flight test for the supersonic transport before FAA certification, and approximately 18,000 hours of ground and flight time on the engine which is finally selected. The 1500-hour flight test program was established after reviewing the flight test time required for the subsonic jets. These aircraft required approximately 1000 hours of flight test time. It should be emphasized, however, that the 1500-hour program is a judgment determination and that it may prove to be desirable to provide additional flight test hours.

There have been suggestions that a supersonic transport should be placed in cargo service for a year or longer before being introduced into passenger service. This approach has been suggested for almost every U. S. transport since 1946, but has not proven feasible in view of the extremely high cost of such a program. Each additional 1000 hours of flight test time during the latter stages of the program is estimated to cost approximately $10 to $15 million, excluding depreciation, insurance, and loss of revenue.

If the airlines believe extended service testing is required after FAA certification, this will be at their expense.

CONTRACTOR SELECTION

As a basic principle the various factors and associated weights which will be used to determine the successful competitors will be made public prior to any phase of the competition. There should be no mystery as to the selection process to be followed, nor can there be any question that the Administrator of the development program must have the final authority to make the selection. In so doing, he should have the recommendations of air carriers, the various interested Government agencies, and public associations that take part in the evaluation processes.

GOVERNMENT ROLE IN THE DESIGN PROCESS

The Government role, after required consultation with the airlines and others, should be to establish the design objectives for the supersonic transport development program, establish the basis for selection of contractors, and maintain current review and evaluation of all phases of the program to ensure that the successful contractors achieve required aircraft characteristics.

The Government should not attempt to provide detailed design solutions, but should make every effort to preserve the normal relationship between manufacturers and air carriers, to the extent feasible.

Assuming a satisfactory supersonic transport results from the development program and is certificated as a commercial transport, the Government should withdraw from the program.

BASIS FOR DEVELOPMENT OF TIME AND COST ESTIMATES

The time and cost estimates in this report are based in part on evaluation of manufacturers' estimates, together with a review of development programs for large military and commercial aircraft. Charts 14 and 15 show detail estimates of the airframe and engine development costs. Chart 16 shows the build up of development costs as the program progresses in time.

The times required to develop the B-58 and the B-70 are not directly comparable to the schedule for the supersonic transport development plan. The objectives of a military development program are substantially different from those for a commercial transport. Military developments must normally adjust to any advance in the state-of-the-art and changes in mission requirements in order to achieve maximum design capability.

The desired characteristics of the supersonic transport can be clearly defined prior to Phase II. It is feasible to establish these requirements more definitively than is possible for military aircraft. Therefore, both cost and time required for development should be somewhat less. The estimate of times required for the development program has been coordinated with individual manufacturers and knowledgeable people in the Department of Defense in order to test their reasonableness.

The cost estimates for engine development seem reasonable in light of past military and commercial experience. Airframe cost estimates were made after a careful evaluation of each manufacturer's proposal. The estimates are subject to revision as the design parameters become more firmly established and the manufacturers' estimates more refined through the competitive processes.

FINANCIAL PARTICIPATION BY AIRFRAME AND ENGINE MANUFACTURERS

The airframe and engine manufacturers should be required to participate in the cost of developing a supersonic transport for an amount not less than 25% of the total program requirements.

The only justification for Government support of the development program is that the risks and costs associated with the program are beyond the financial capability of the airframe and engine manufacturers. (Chart No. 17)

To assume, however, that the supersonic transport cannot be produced with a reasonable return to the manufacturers is to assume that the development program will fail to achieve a transport with requisite economic characteristics. Unless the manufacturer

demonstrates his faith in the commercial supersonic transport by undertaking to share a part of the program, there is doubt as to a justification for funding by the Government. The 25% participation by the manufacturers is a minimum. Costs in excess of the manufacturers' development contracts will be prorated as follows:

a) 1st $100,000,000 in excess of contract price - manufacturer to pay 75 per cent, government to pay 25 per cent.

b) All costs over $100,000,000 in excess of contract to be paid by the manufacturer.

Unsuccessful contractors would be reimbursed for all development costs related to the Phase II competition after delivery of all design information, hardware, patents, and rights to the Government.

If it is assumed that the total cost of the supersonic transport development program will be $1 billion, the 25% participation requirement would result in the manufacturers contributing $250 million of this amount. The engine manufacturer would be required to contribute approximately $90 million, and the airframe manufacturer $160 million. These amounts are consistent with airframe and engine development cost estimates.

If two or more airframe and/or engine manufacturers collaborate, the impact on each company would be reduced.

It is also possible that the prime manufacturer will require participation by the subcontractors in meeting the financial commitment.

It should be emphasized that the financial participation requirement is in itself an effective evaluation of the soundness of the manufacturers' proposals and will reflect their confidence in their ability to delivery a sound commercial transport.

PARTICIPATION BY AIRLINES

The air carriers have a vital interest in the development of the supersonic transport. Many of the design requirements for the aircraft will result from the recommendations of the airlines.

Unless the air carriers demonstrate their confidence in the development program, there may be doubt that the required Government expenditures would be justified. Under these circumstances it seems appropriate that the airlines should share at least a part of the risk involved in the development program. The economic and operational performance of the aircraft should be reasonably predictable at the end of Phase II. Therefore, the air carriers should be required to place orders for transports within six months after completion of Phase II. Each order for an aircraft should be accompanied by a payment of approximately $200,000 in the nature of a royalty to defray a portion of development costs. The sequence of these orders would determine delivery priorities. If sufficient interest through placement of orders for a significant number of aircraft is not demonstrated by the airlines during this period, the Government should terminate the development program.

All aircraft ordered after this initial period will require a $500,000 royalty.

In addition to the royalty payments stipulated above, the air carriers should be required to repay the Government's development contribution through the assessment of a royalty of approximately 1.5% of the revenue generated by the aircraft over a 12-year period. The royalty assessment will be terminated as soon as the Government's share of the development program, on which no interest will be charged, has been repaid.

DECISION POINTS

The Government should proceed with the supersonic transport development program with expedition. However, in a program of this nature and in consideration of the potential risks, decision points should be clearly delineated to provide opportunities for re-direction or termination of the program.

The primary decision points will be:

1. After completion of the Phase I competition if it is clear that requisite aircraft characteristics or program costs are not acceptable.

2. After completion of the Phase II competition if it is clear that requisite aircraft characteristics or program costs are not acceptable.

3. If manufacturers are unwilling to meet the 25 percent participation requirement.

4. If airlines do not order a significant number of transports within six months after completion of Phase II.

5. If the prototype aircraft does not demonstrate the required characteristics after 50 hours of flight test.

PRODUCTION PROGRAM

COST ESTIMATES

Manufacturers' estimates of the cost of production aircraft, which have been received to date, have varied widely due to design assumptions, development approaches, and type of aircraft structural material.

The average of the estimates of four airframe manufacturers for a Mach 3 steel/titanium aircraft is $22.6 million per unit. The manufacturers' estimates include a normal 20 % profit and warranty but do not reflect amortization of development costs.

It is estimated that a Mach 2.2 aluminum airplane, substantially satisfying the design characteristics, could be produced from $13 to $15 million.

It is estimated that a Mach 2.5 transport, using titanium as the primary structural material, would cost approximately the same as the Mach 3 steel/titanium airplane. There is some indication, however, that the manhours required to fabricate a titanium aircraft could be as much as 10% lower than for a steel aircraft. At the present time, the cost of titanium is substantially higher than steel, but it can reasonably be assumed that this cost would be sharply reduced in the future if as many as 200 supersonic transports were produced.

It appears at this point that titanium, because of its superior strength/weight characteristics, offers the most feasible means of ensuring that the transport aircraft will have the proper payload capability in relation to its gross weight.

FINANCING PRODUCTION COSTS

The Government will not fund production of the supersonic transport.

The manufacturers will be required to finance production tooling as well as "work in process." These two requirements may, at their peak, be as high as $800 million. This might conceivably require Government assistance in the form of guaranteed loans. The exact amount of this financial support will depend upon aircraft characteristics and related costs. It is apparent, however, that the difference in production costs between a Mach 2.2 and a Mach 3 transport may be as high as $10 million. This would result in a substantial increase for "work in process" for a Mach 3 compared to a Mach 2.2 transport.

The production "work in process" requirement and the need for Government support cannot be determined at this time.

Financing of commercial transport aircraft normally requires the airlines to make an initial down payment of approximately 5% of the delivered price from two to three years in advance of delivery, with total progress payments approximating 33% of the delivered price being made at least six months prior to acceptance. The balance, or 67%, of the price is payable on delivery of the aircraft. This traditional schedule of progress payments may have to be substantially increased to meet the "work in process" requirements of the manufacturer.

Another consideration affecting the manufacturer's capability to finance the "work in process" is the potential contributions which can be made by subcontractors. All of the airframe manufacturers anticipate that approximately 50 percent of the production work will be provided by subcontractors. This will permit a sharing of production financial requirements by a large number of corporations.

ESCALATION OF DEVELOPMENT AND PRODUCTION COSTS

Development and production costs for the supersonic transport will increase in the years ahead in relatively the same manner as in related industries and in conformance to inflationary influences.

It is estimated that, during the period of the development and production programs, there may be an annual cost escalation in the order of 4 percent, due to increased labor and material costs.

It should be pointed out, however, that, to some degree, escalation will be offset by productivity increases. Development and use of new or improved materials including steel and titanium alloys may result in substantial downward trend of costs.

The application of advanced production techniques such as chemical milling, fusion welding of titanium, etc., may also prove to be a significant factor in cost reduction.

Therefore, in considering the actual cost of any future transport, it is reasonable to assume that escalation may not be as high as 4 percent per annum.

OTHER TECHNICAL CONSIDERATIONS

NOISE ON THE GROUND

The supersonic transport will require engines with substantially greater thrust than any subsonic transport aircraft flying today. This means that, even with substantial progress in the techniques of reducing jet engine noise, the supersonic transport will tend to have higher noise levels on the airport than the largest subsonic transport.

The supersonic transport on take-off, however, may be less objectionable to airport neighbors than subsonic jets, since it will have the capability of climbing to higher altitudes before it reaches the airport boundary and a point approximately three miles from the beginning of the take-off roll. (Chart No. 18).

On approach to the airport over populated areas, the engine compressor whine will be at least as quiet as that of subsonic jets, and may achieve a substantially lower noise level because of the extended inlet ducts. (Chart No. 19). It is not certain at this time that jet engine exhaust noise will be any lower than that produced by today's large jet aircraft.

OZONE

At high altitudes, concentrations of ozone can adversely affect nasal, throat, and lung passages of passengers and crew. The effects of concentrations of ozone can be precluded through the use of unsophisticated filtering systems. Such systems are in existence today, and there is no doubt about the ability of industry to deal effectively with this problem in the supersonic transport.

DECOMPRESSION

Cabin decompression due to structural failure was a serious problem in the first British Comet. The fail-safe structures and pressurization systems developed by the United States airframe manufacturers have successfully dealt with this problem in the subsonic jets.

The supersonic transport will fly at higher altitudes than the subsonic jets and this will increase the potential magnitude of this problem. However, the industry's demonstrated ability can be expected to meet supersonic transport requirements.

RADIATION

Radiation effects from major solar disturbances are more prevalent in the northern latitudes. These disturbances occur on the average of once or twice a year. Current forecasting techniques can predict these disturbances, which may last as long as 24 hours, about fifteen minutes in advance of their occurrence. With this warning, the hazard can be avoided by descending to lower altitudes.

During periods of major solar disturbances, aircraft can operate safely at altitudes less than 50,000 feet or at higher altitudes in southern latitudes. These available alternatives should preclude interruption of scheduled flights.

Radiation encountered by the supersonic transport will not, according to the best information available, be a hazard to either passengers or crew.

AIRPORT REQUIREMENTS

Increased costs of acquiring land and lengthening runways have become a major concern. A firm FAA design requirement limiting take-off field lengths for supersonic transports to 10,500 feet has been established.

Acceptable take-off performance will be achieved through the use of high thrust engines required for transonic acceleration at high altitudes. It is generally agreed that, because of the large amounts of fuel consumed in flight, the transport will be relatively light in normal approach configuration. This factor, together with aerodynamic developments, should result in favorable landing characteristics.

AERODYNAMIC NOISE LEVEL

Objectionable cabin noise is caused primarily by aerodynamic turbulence. Sound pressure levels are largely a function of indicated air speed and are relatively insensitive to Mach number. Aerodynamic noise will be higher for supersonic aircraft than subsonic aircraft, but cabin noise levels in supersonic transports can be controlled by known soundproofing techniques.

AIR TRAFFIC CONTROL

Traffic control procedures and facilities must keep pace with the problems associated with supersonic speed. Improved communication and navigation systems are expected to be available for commercial transports in the 1970's.

Reserve fuel requirements are determined by the operational factors of navigation, air traffic control, alternate destination, dispatching, and landing clearances.

Improvements in weather forecasting, air traffic control, the relative insensitivity of the supersonic transport to winds, and all-weather landing systems may ultimately permit reduction of reserve fuel requirements. If this requirement can be reduced, the supersonic transport payload characteristics could be substantially enhanced.

FLYING QUALITIES

The supersonic transport must have acceptable take-off and landing distances, reasonable flexibility of operating altitudes and speeds, and should have flight characteristics as good as present jet transports. Stability in low and high speed flight both during normal and emergency conditions is necessary. Additionally, acceptable flight characteristics for any reasonable failure of aircraft systems is mandatory. It is believed that satisfactory solutions to these problems can be achieved by the time of certification for passenger service.

AIRPORT ACCESSIBILITY

One of aviation's prime problems today is the amount of time required for travelers to reach major airports from various points within metropolitan areas. It is to be expected that major progress will have been made in this area by the time the supersonic transport becomes operational. The high airborne speed of the aircraft should not be partially cancelled out by excessive travel time on the ground.

MANAGEMENT ORGANIZATION

CONCEPTS

The scope of the supersonic transport development program will require substantial Government financial participation. In order to ensure that public funds are expended effectively, it will be necessary for the Government to exercise reasonable supervision over all aspects of the program.

The end result, however, of the transport program must be a commercially satisfactory aircraft. Therefore, it is essential that the air carrier industry be given every reasonable opportunity to participate in the design and operational aspects of the program to ensure that the product will be commercially feasible.

As far as possible, the normal relationships which exist between airframe and engine manufacturers and air carriers during the development of a new commercial aircraft should be encouraged.

Decisions affecting the development program, however, should not be on the basis of committee action. Therefore, a single responsible Government official must have final authority to make the necessary decisions after the basic policy has been established by the Administration and the Congress.

The Government should have primary interest in the design characteristics of the aircraft rather than in how these characteristics are achieved. The Government's role, therefore, is to develop the best competitive U. S. supersonic transport without attempting to delineate detailed design requirements, but at the same time ensuring that the basic requirements of the air carriers and the interests of the United States Government are fully protected.

ASSIGNMENT OF RESPONSIBILITY FOR MANAGEMENT OF THE DEVELOPMENT PROGRAM

The President of the United States has placed upon the Federal Aviation Agency the responsibility for supervision of the supersonic transport development program.

The intent is to establish an organization headed by a Deputy Administrator, reporting to the President through the Administrator of the Federal Aviation Agency.

It is anticipated that all funds provided by Congress for the development program will be clearly de gnated as separate and apart from normal FAA appropriations.

The management organization will be a separate entity under the Administrator of the Federal Aviation Agency. It will be necessary for the management organization, from time to time, to call on the resources of the Federal Aviation Agency and other Government agencies such as NASA and Department of Defense in order to accomplish the various program objectives.

STAFFING REQUIREMENTS

The staffing requirements of the management organization should be kept to a minimum consistent with the responsibilities placed upon it. It is anticipated that this organization should require a staff of no more than 100.

The size of the organization should be limited, but it should have the authority to request assistance from other Government agencies such as NASA and Department of Defense as may be required for relatively short periods of time during various phases of the program. The management responsibility for the development program does not require a large staff, but does require a high degree of competency in the various technical areas as well as a high order of administrative capability.

FREE WORLD AIR TRAFFIC DISTRIBUTION BY MILEAGE BLOCKS 1975

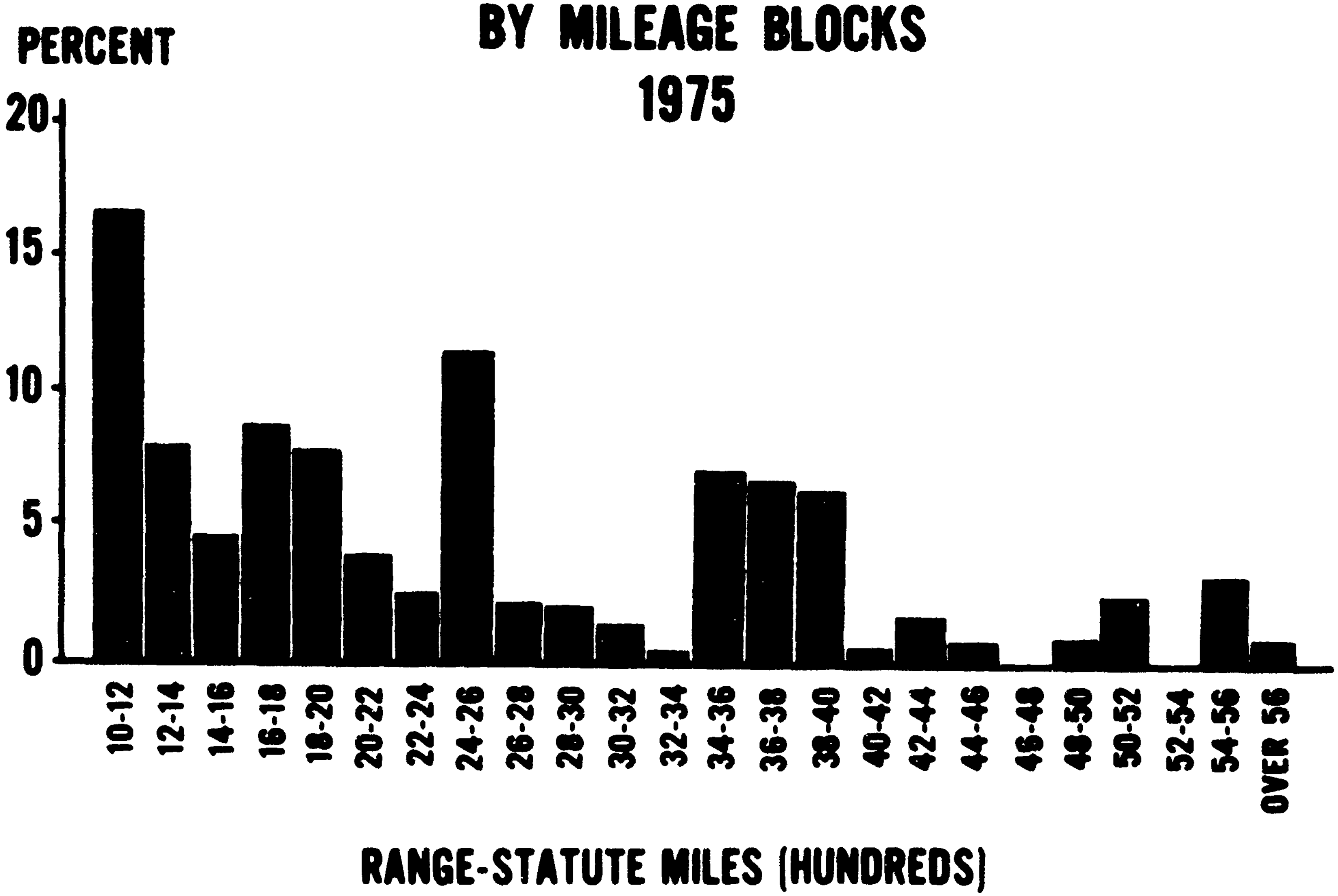


Chart 1

PRODUCTIVITY 150 PASS. AIRCRAFT 55% LOAD FACTOR

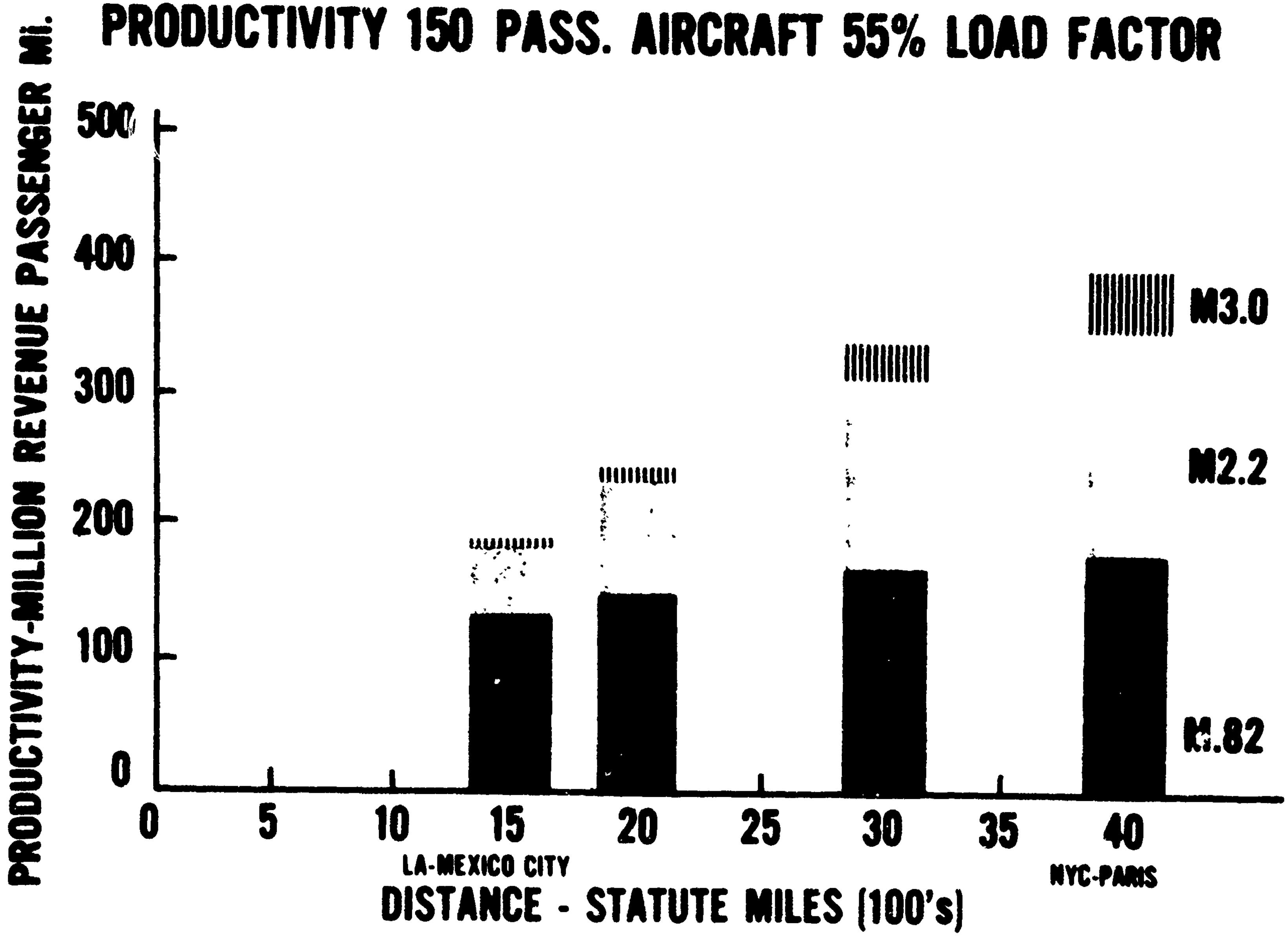


Chart 2

BLOCK TIMES VS. RANGE

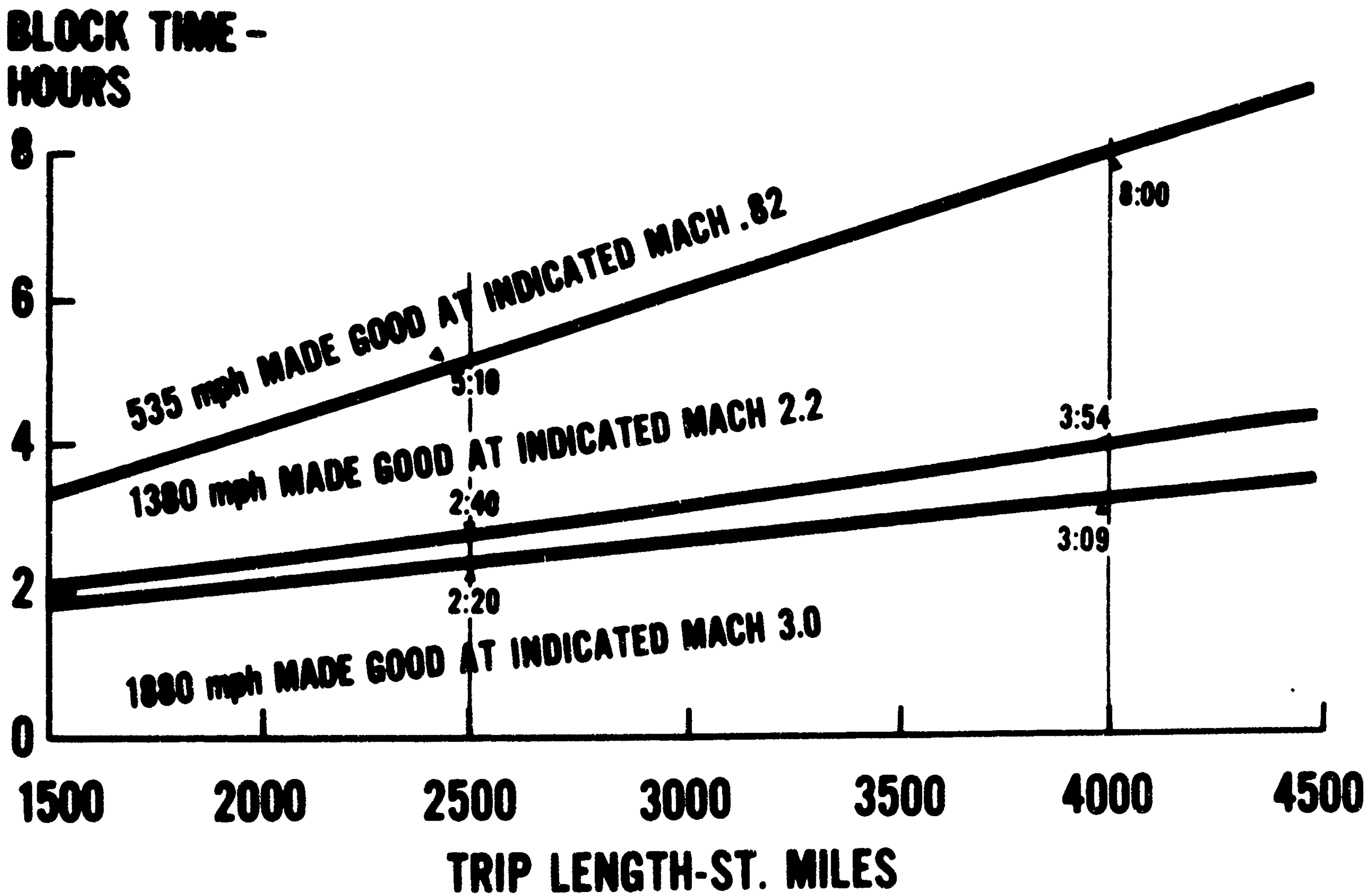


Chart 3

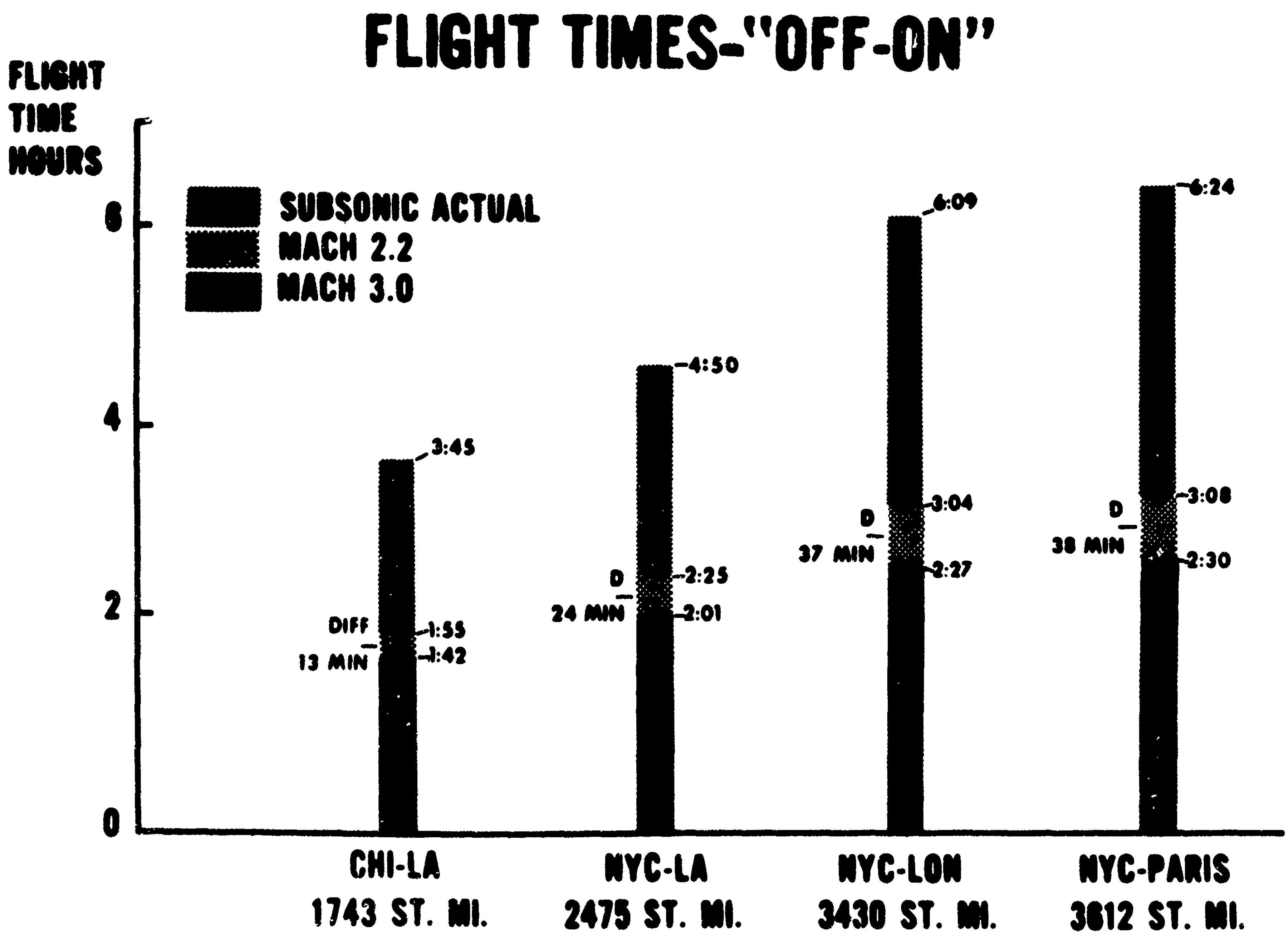
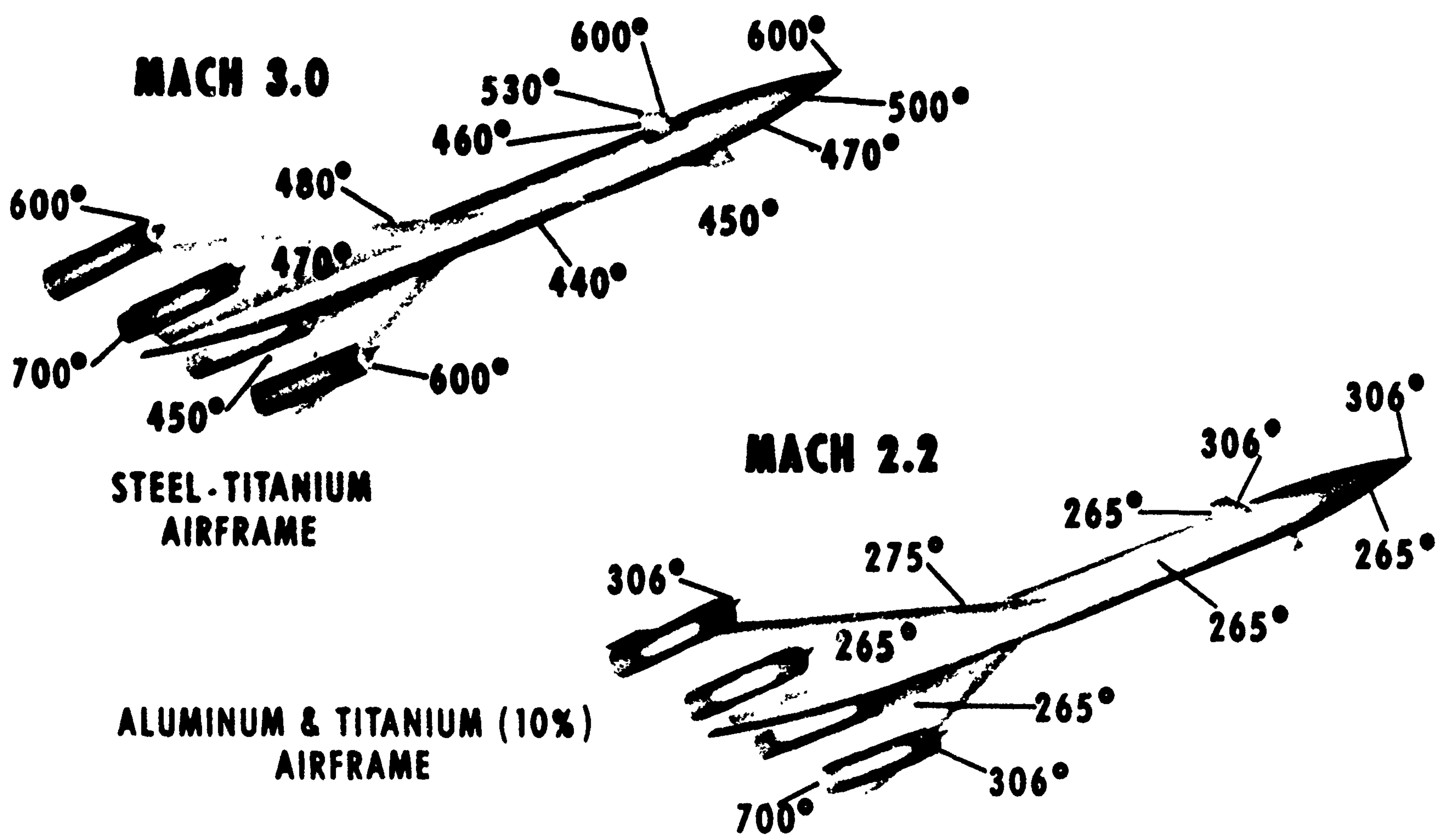

FLIGHT TIMES-"OFF-ON"
FLIGHT TIME HOURS
SUBSONIC ACTUAL
MACH 2.2
MACH 3.0
6
4
2
0
3:45
1:55
1:42
DIFF
13 MIN
4:50
2:25
2:01
D
24 MIN
6:09
3:04
2:27
D
37 MIN
6:24
3:08
2:30
D
38 MIN
CHI-LA
1743 ST. MI.
NYC-LA
2475 ST. MI.
NYC-LON
3430 ST. MI.
NYC-PARIS
3612 ST. MI.

Chart 4

SST SURFACE TEMPERATURES



STEEL-TITANIUM
AIRFRAME

ALUMINUM & TITANIUM (10%)
AIRFRAME

Chart 5

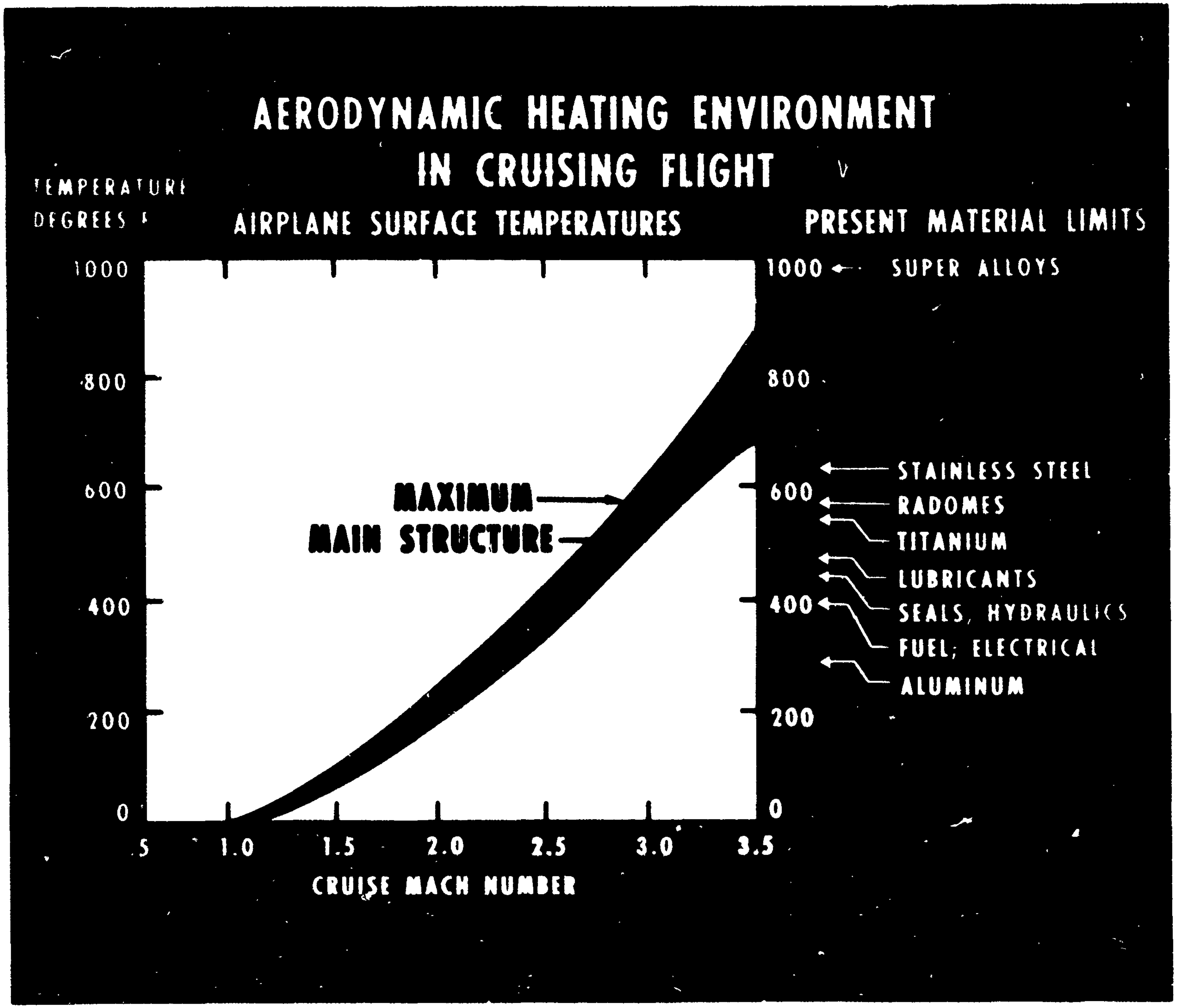

AERODYNAMIC HEATING ENVIRONMENT
IN CRUISING FLIGHT
TEMPERATURE
DEGREES F
AIRPLANE SURFACE TEMPERATURES
PRESENT MATERIAL LIMITS
1000
800
600
400
200
0
SUPER ALLOYS
STAINLESS STEEL
RADOMES
TITANIUM
LUBRICANTS
SEALS, HYDRAULICS
FUEL; ELECTRICAL
ALUMINUM
MAXIMUM
MAIN STRUCTURE
.5
1.0
1.5
2.0
2.5
3.0
3.5
CRUISE MACH NUMBER

Chart 6

ESTIMATED SONIC BOOM OVERPRESSURES

MACH 2.5 SUPERSONIC TRANSPORT

MAXIMUM TAKE-OFF GROSS WEIGHT OF 350,000 POUNDS

FUEL REDUCED FOR SHORT STAGE LENGTHS

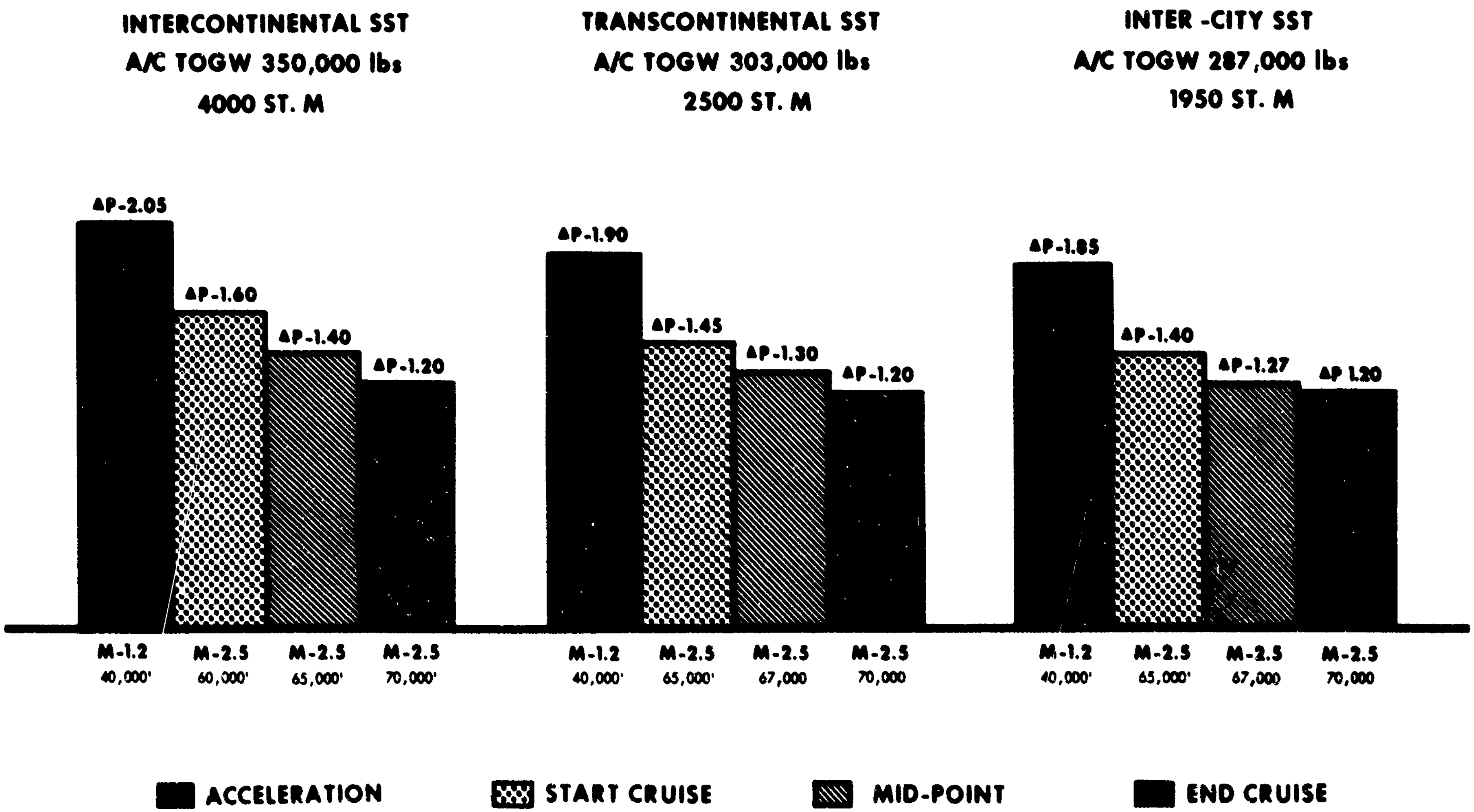


Chart 7

INTERIM PREDICTION OF SONIC BOOM GROUND EFFECTS

SONIC BOOM GROUND OVERPRESSURE LBS/SQ FT.	
3.0	WIDESPREAD PUBLIC REACTION POSSIBLE DAMAGE TO WINDOWS AND PLASTER
2.5	INCIPIENT DAMAGE-SIGNIFICANT PUBLIC REACTION CLOSE RANGE THUNDER OR EXPLOSION.
2.0	PROBABLE PUBLIC REACTION-PARTICULARLY AT NIGHT
1.5	SOME SCATTERED PUBLIC REACTION NO DAMAGE TO GROUND STRUCTURES
1.0	ACCEPTABLE-NO SIGNIFICANT PUBLIC REACTION- DISTANT EXPLOSION
0.5	ACCEPTABLE-DISTANT THUNDER

INVESTIGATOR: NATIONAL OPINIONS RESEARCH CENTER (U OF CHICAGO)

Chart 8

OPERATING PROFIT COMPARISON

NEW YORK - PARIS RANGE
60% LOAD FACTOR

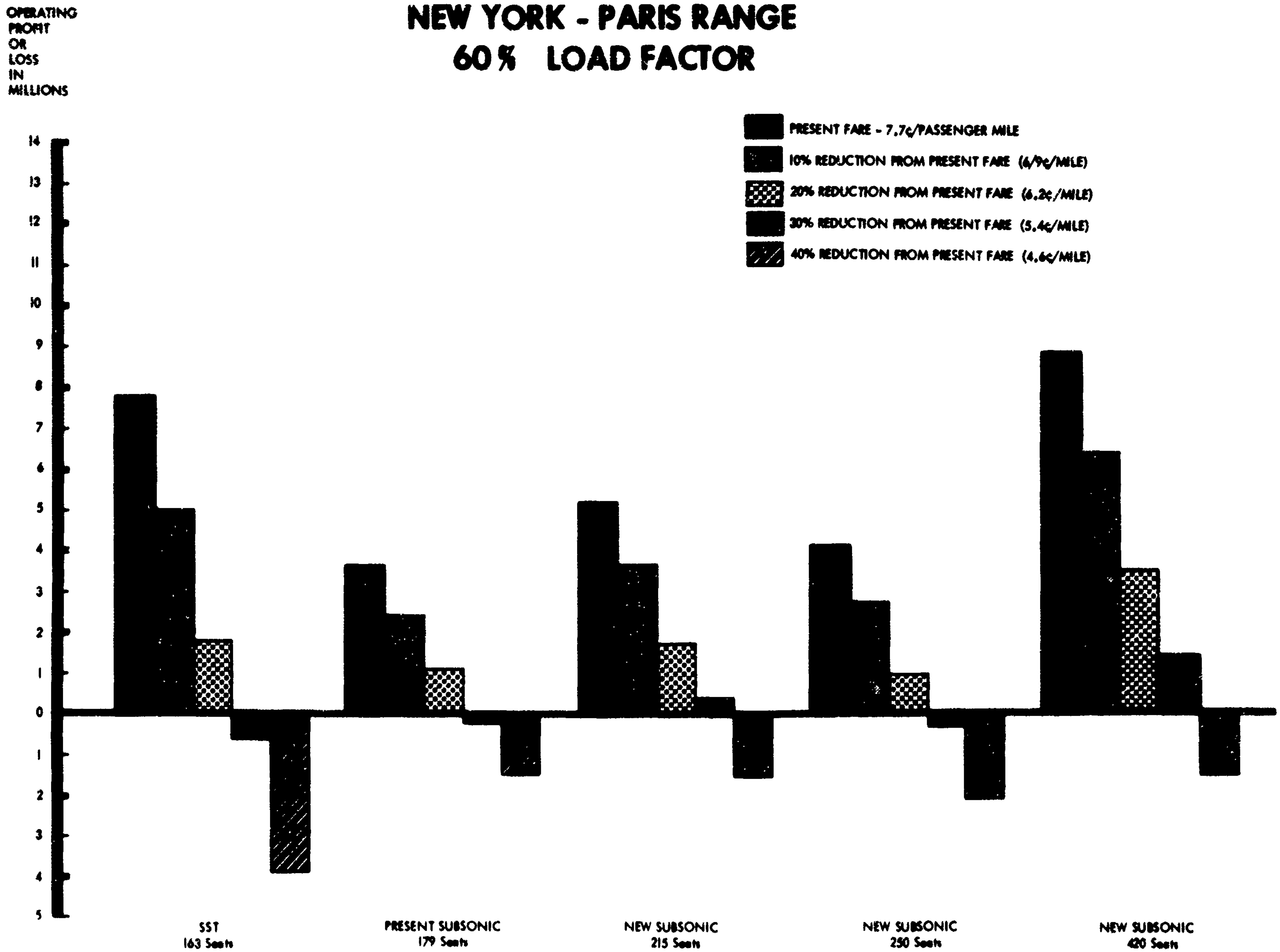


Chart 9

OPERATING PROFIT COMPARISON

NEW YORK - PARIS RANGE
REALISTIC LOAD FACTORS

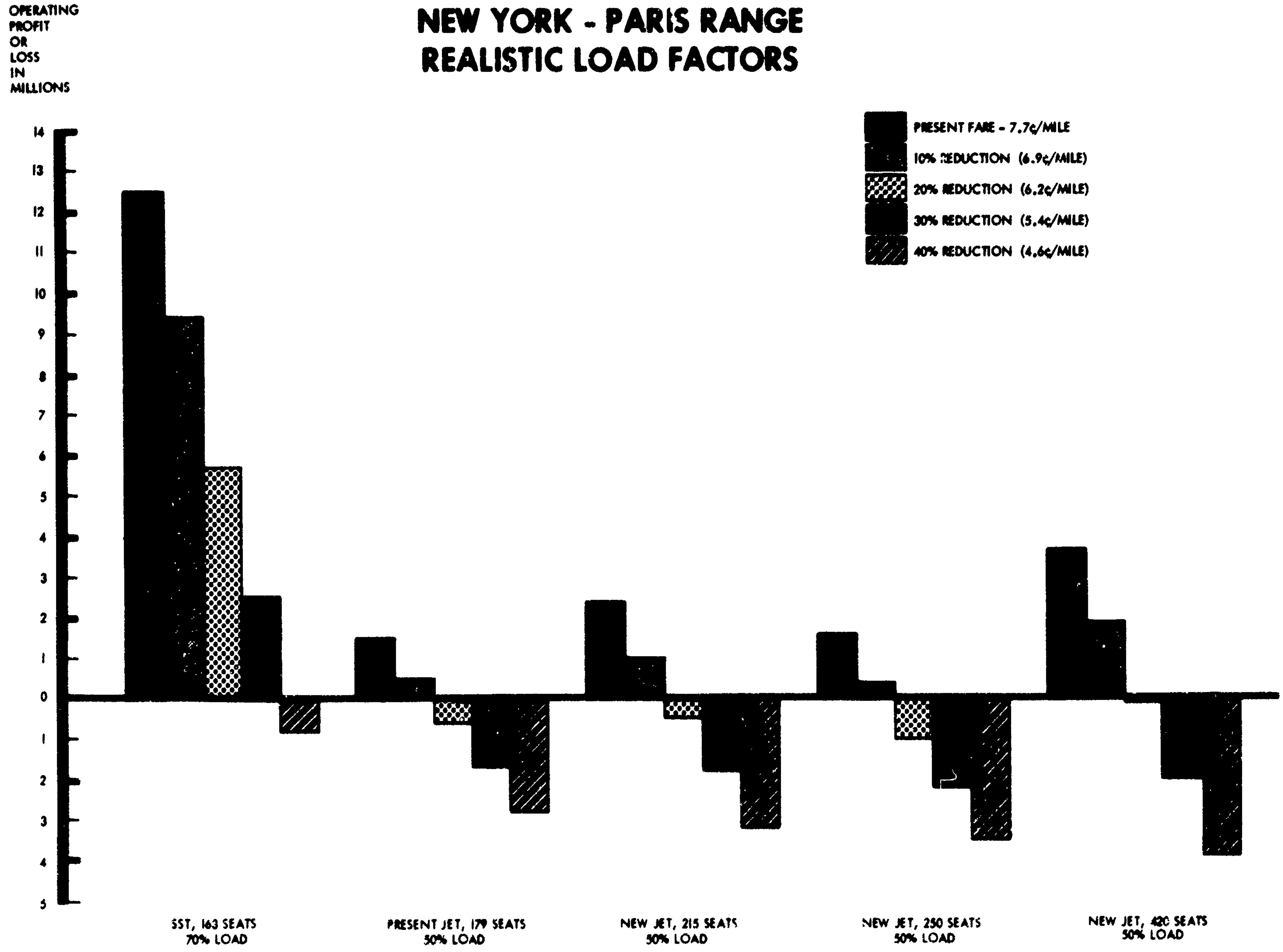


Chart 10

Airplane Characteristics

Airplane Item	Supersonic Transport	Subsonic Jet "Present" *	Subsonic Jet "Advanced"	Subsonic Jet "Air Bus"	Subsonic Jet "Air Bus"
Source	FAA	SRI	SRI	Dept.of Comm.	Douglas Aircraft
Number of Passengers (Economy-34" Pitch)	163	179	215	250	420
Takeoff Gross Weight, lbs.	350,000	328,000	400,000	---	467,000
Maximum Payload, lb.	35,000	54,000	50,000	---	100,000
Nominal Cruising Speed	1650 mph (M2.5)	570	610	450 mph	450 mph
Cruise L/D	8.25	---	---	17	17
Cruise SFC	1.43	---	---	---	0.77
Price (Depelopment cost not amortized)	$22,600,000	6,650,000	7,340,000	7,600,000	9,356,000
Utilization - hours/year	3,000	3,000	3,000	3,000	3,000
Cost Basis					
Crew - current strength	150% ATA	ATA	ATA	---	ATA
Depreciation					
Airframe					
Life	12 years	12 years	10 years	12 years	---
Spares	10%	10%	10%	10%	---
Residual value	15%	15%	15%	15%	---
Engines					
Life	7 years	8 years	8 years	8 years	---
Spares	50%	50%	50%	50%	---
Residual value	15%	15%	15%	15%	---
Electronics					
Life	5 years	5 years	5 years	5 years	---
Spares	25%	25%	25%	25%	---
Residual value	0	0	0	0	---
Insurance (rate per year)	5%	5%	5%	5%	---

* Increased capacity

Chart 11

Airplane Item	Supersonic Transport	Subsonic Jet "Present" *	Subsonic Jet "Advanced"	Subsonic Jet "Air Bus"	Subsonic Jet "Air Bus"
Fuel - Domestic	11¢	11¢	11¢	---	---
International	12¢	12¢	12¢	---	---
Oil Cost/hour	$6	$2	$2	---	---
Maintenance - $1 hr./1,000 lb. mnfg. weight empty	$2.75	$2.50	$2.50	---	---
Direct Operating Costs - ¢1 SM					
New York-Paris 4000 stat. mi.	1.25¢	1.13¢	1.06¢	1.24¢	0.87¢
New York-Los Angeles 2463 stat. mi	1.40	.88	85	1.37	.78
Chicago - Los Angeles 1751 st.mi.	1.46	.90	.87	1.41	.80
Chicago - New York 724 st. mi.	1.63	.99	1.02	1.55	.86
Indirect Operating Costs - ¢/SM					
International	2.15¢	2.15¢	2.15¢	2.15¢	2.15¢
Domestic	1.63	1.63	1.63	1.63	1.63
Revenue - ¢/SM New York-Paris (econ)	7.7¢	7.7¢	7.7¢	7.7¢	7.7¢
New York-LA (coach)	5.7	5.7	5.7	5.7	5.7
Chicago-LA "	6.2	6.2	6.2	6.2	6.2
Chicago-New York "	6.8	6.8	6.8	6.8	6.8
Block Speed mph					
New York - Paris	1320	525	562	437	437
New York - LA	1180	513	550	428	428
Chicago- LA	1050	490	538	418	418
Chicago-New York	710	420	460	358	358

* Increased capacity

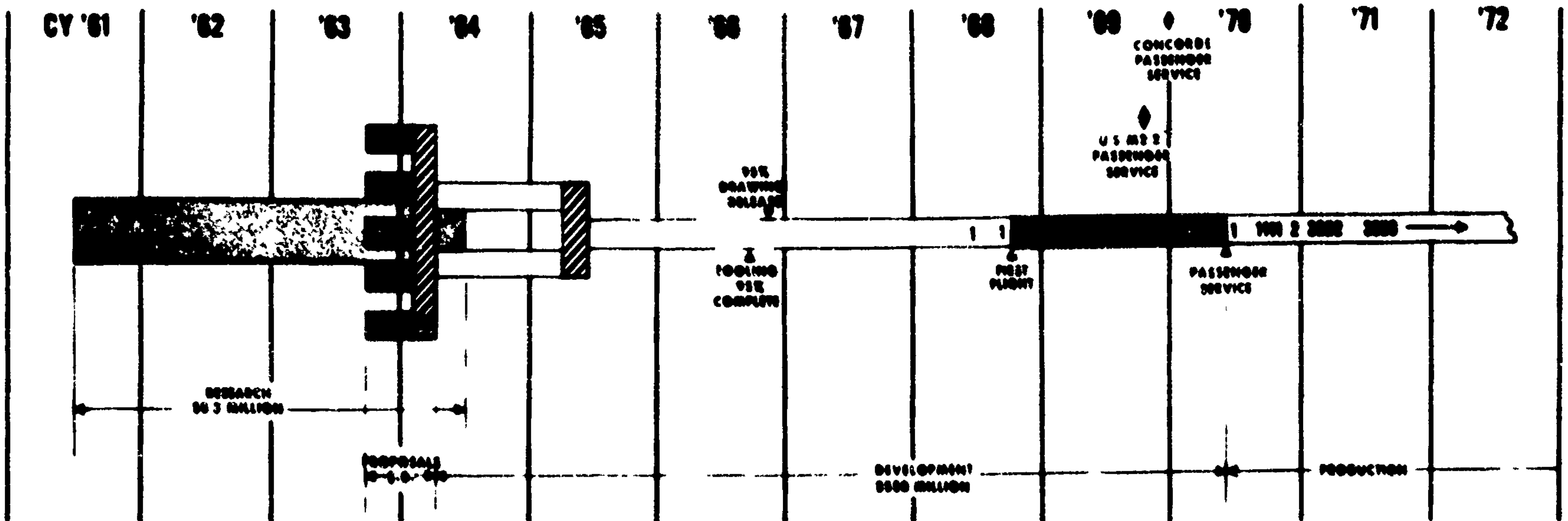
Chart 11 (continued)

ESTIMATED SUPERSONIC TRANSPORT CHARACTERISTICS

ITEM	M 2.5 SST (REALISTIC GOALS)
Ariplane Weights (Percent of Gross Weight)	
Fuel	48%
Payload	10%
Crew, Furnishings, Equipment	10%
Engines	9%
Structure	23% (Titanium)
Cruise Speed	M 2.5
Number of Passengers	163
Fuel Reserves	6%
Maintenance Costs ($ per hr./1000 lb.)	$2.75
Fuel Cost (International)/gal.	.12¢
Insurance (annual)	5%
Take-off Gross Weight	350,000 lb.
Payload	35,000 lb.
Lift/Drag Ratio	8.25
Specific Fuel Consumption	1.43 lb./hr./lb.
Block Speed (New York - Paris)	1320 MPH
Direct Operating Costs (New York - Paris)	1.25¢/SM

Chart 12

SST DEVELOPMENT PROGRAM



SST ENGINE DEVELOPMENT PROGRAM

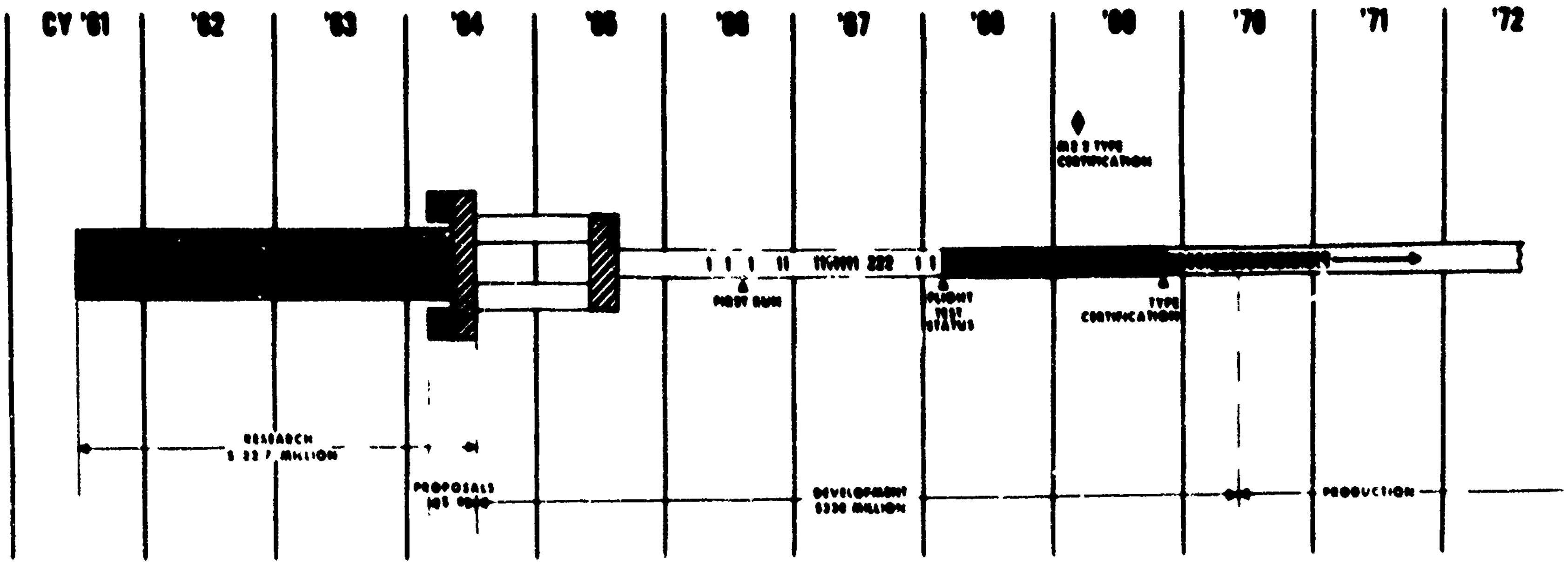


Chart 13

ESTIMATED AIRFRAME DEVELOPMENT COSTS
MACH 3 STEEL-TITANIUM

DEVELOPMENT ENGINEERING	$ 160 MILLION
TESTS AND TEST ARTICLES	70
FLIGHT TESTS (1500 HOURS)	45
REFURBISH 5 FLIGHT TEST AIRCRAFT	20
PROTOTYPE COSTS	
TOOLING	45
FABRICATION	75
MATERIALS (INCLUDING DEVELOPMENT)	58
ENGINES (INCLUDING 50% SPARES)	12
SPARES AND SUPPORT EQUIPMENT	40
TOTAL	$ 525

Chart 14

ESTIMATED DEVELOPMENT COST
SST ENGINE PROGRAM MACH 2.5-3.0

DEVELOPMENT ENGINEERING	$88	MILLION
COMPONENT EVALUATION	26	
FACTORY TEST ENGINES (HARDWARE)	136.5	
DEVELOPMENT PROGRAM TOOLING	16	
TEST & EVALUATION	58.5	
TYPE CERTIFICATION	325.0	
AIRCRAFT CERTIFICATION FLIGHT PROGRAM	13	
TOTAL	$338.0	

Chart 15

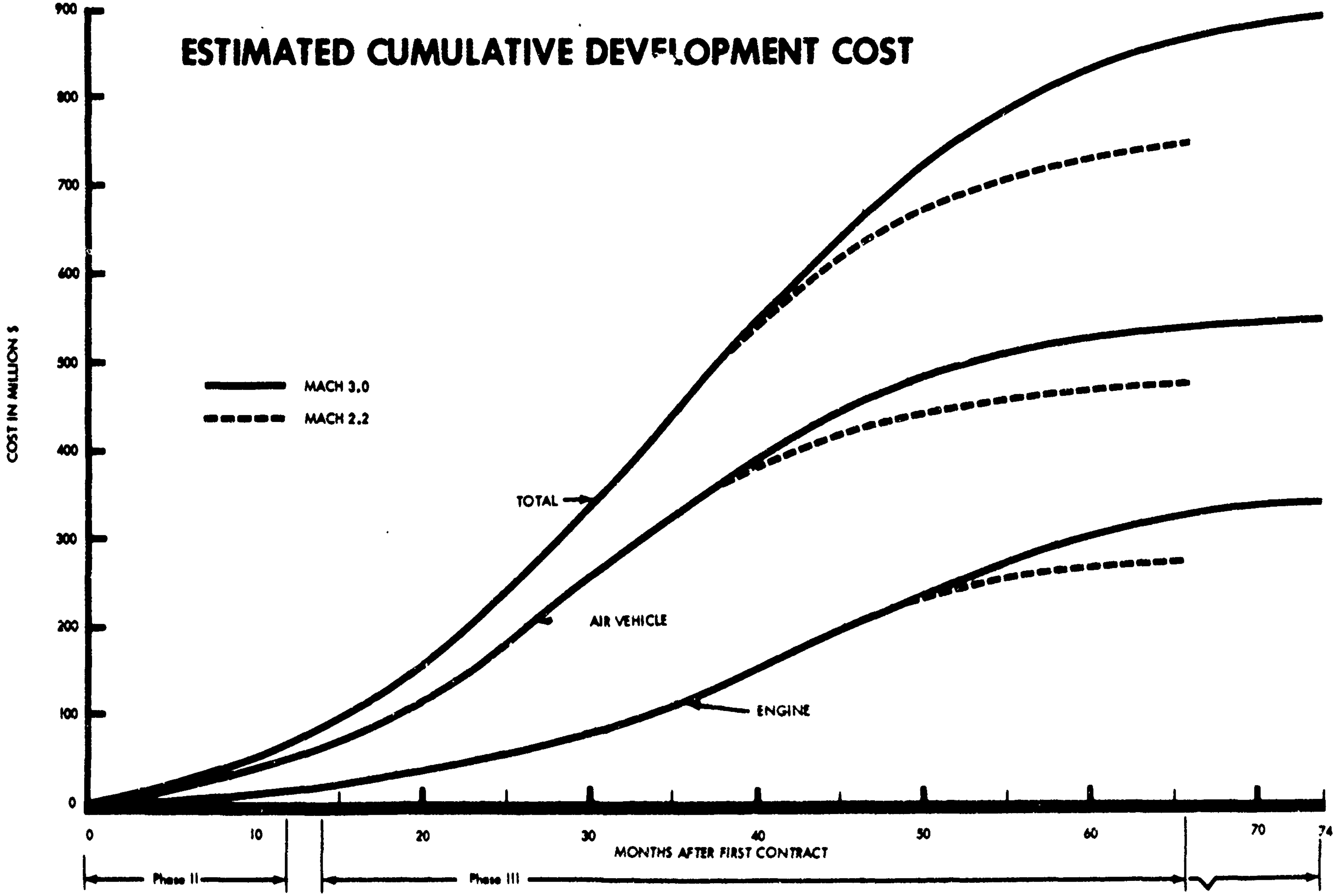

ESTIMATED CUMULATIVE DEVELOPMENT COST
COST IN MILLION $
900
800
700
600
500
400
300
200
100
0
MACH 3.0
MACH 2.2
TOTAL
AIR VEHICLE
ENGINE
0
10
20
30
40
50
60
70
74
MONTHS AFTER FIRST CONTRACT
Phase II
Phase III

Chart 16

TOTAL CAPITAL RESOURCES OF THE AIRCRAFT MANUFACTURERS IN RELATION TO SST DEVELOPMENT COSTS

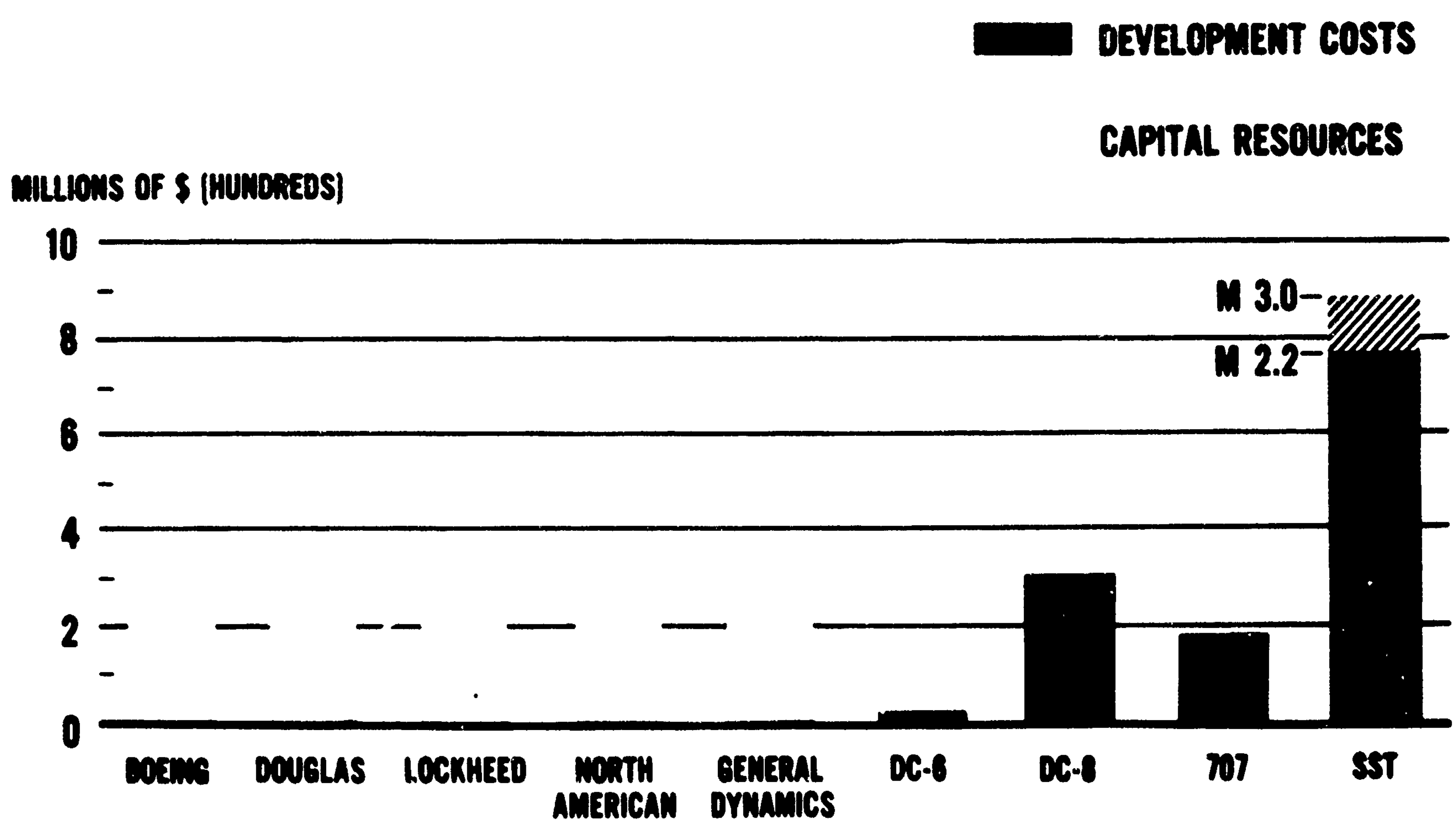


Chart 17

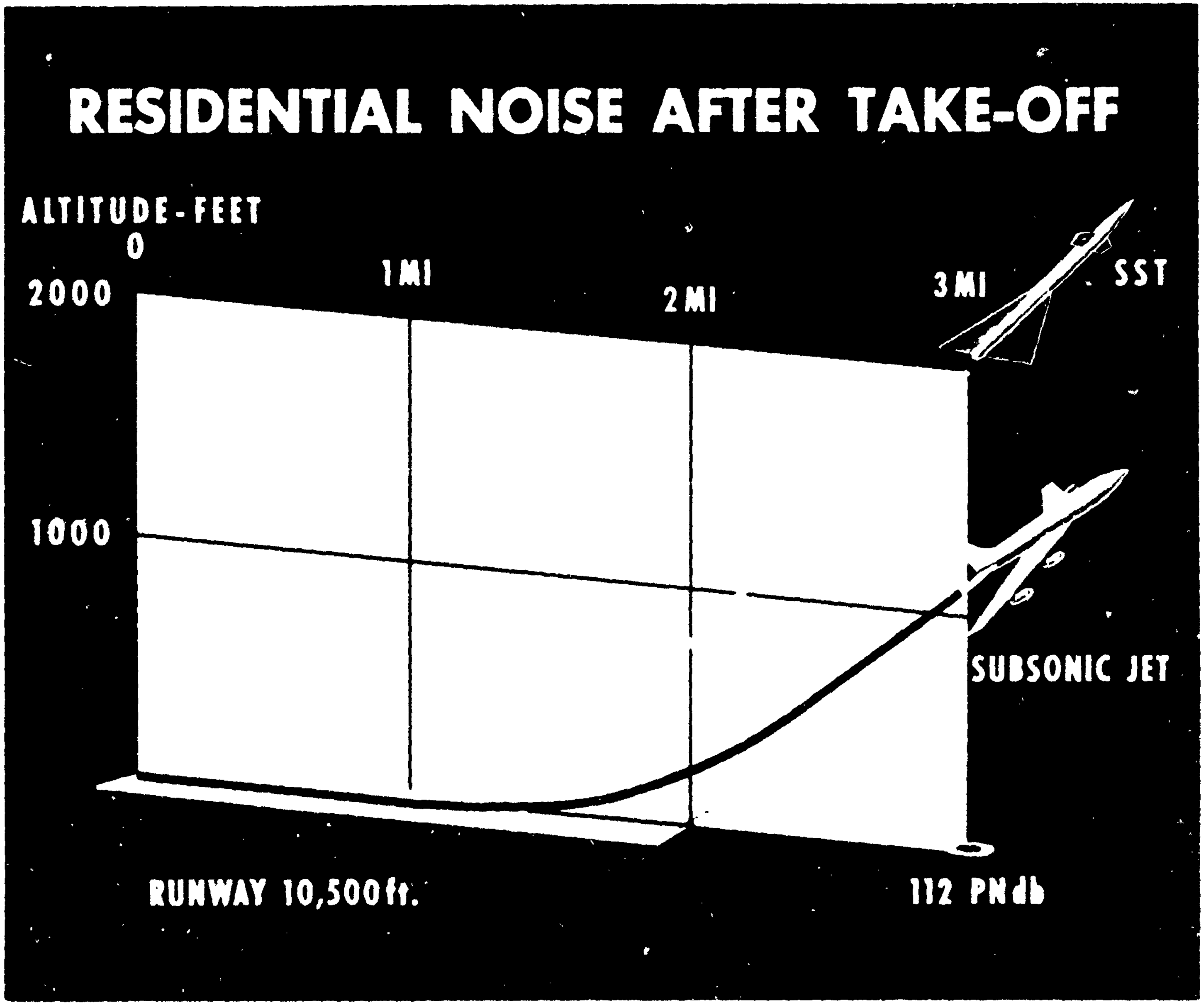

RESIDENTIAL NOISE AFTER TAKE-OFF
ALTITUDE-FEET
0
2000
1000
1MI
2MI
3MI
SST
SUBSONIC JET
RUNWAY 10,500ft.
112 PNdb

Chart 18

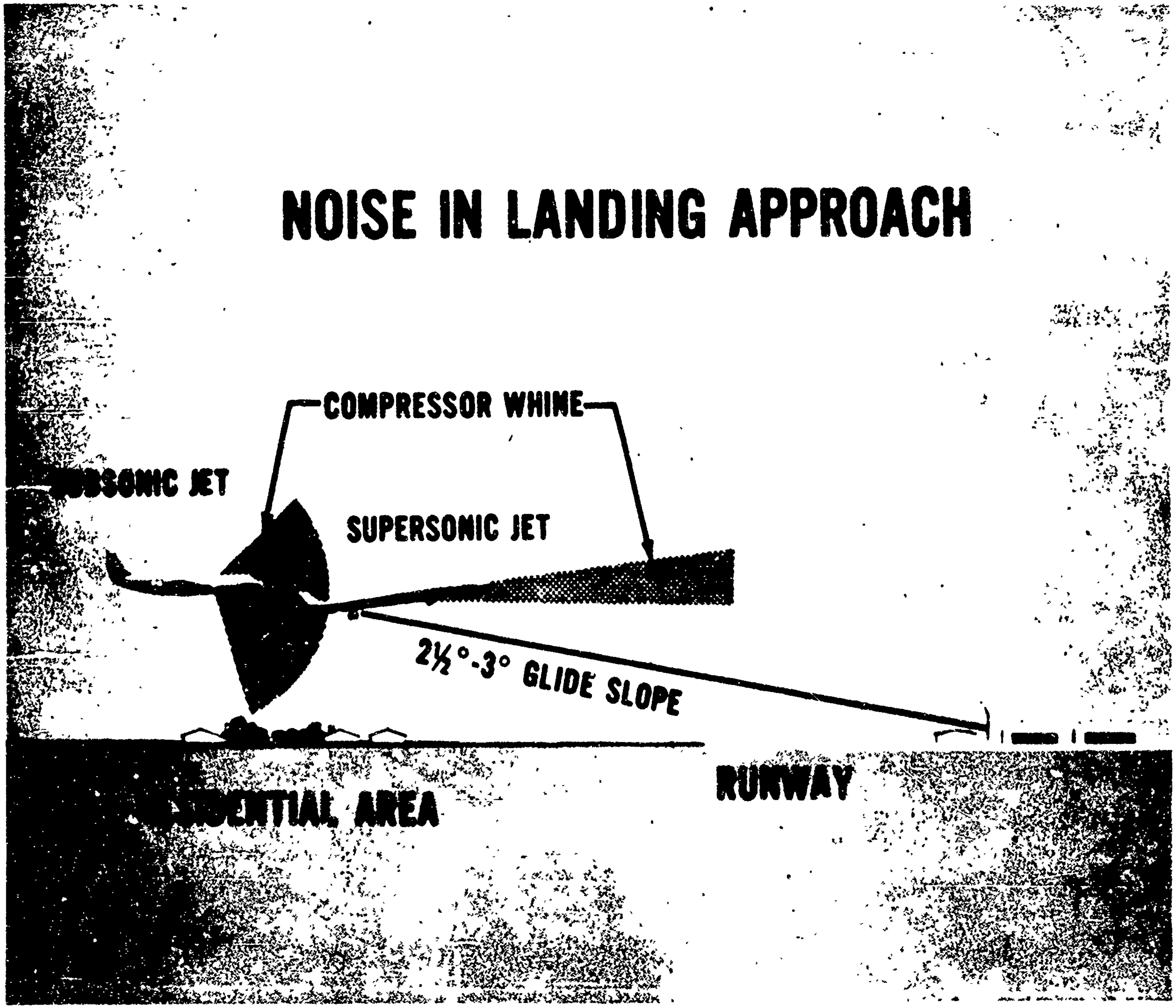

NOISE IN LANDING APPROACH
COMPRESSOR WHINE
SUPERSONIC JET
2½°-3° GLIDE SLOPE
RUNWAY
AREA

Chart 19